insparK BioBeyond Lesson by Lesson Cheatsheet

Cheatsheet FAQ

What is the purpose of this document?

As an instructor we appreciate that you may be juggling a number of classes, with little time to prepare for this course. This may be the first time you have used Inspark courseware and you will need to be supporting your students while they take *BioBeyond*. The purpose of this document is to provide a lesson-by-lesson cheatsheet that should help prepare you in approximately 20 minutes per lesson. You may have the Inspark TAs and Technical Support answering student questions in Piazza (or some other online discussion tool), but you are expected to monitor these questions and respond where possible, in addition to endorsing good responses. This document provides you with the major misconceptions/issues students might have. You may also like to use the Smart Sparrow Analytics to actually see what your students struggled with, but you may not have had time to do that. This document references specific screens in the lessons and we encourage you to work through the Activity Walk-through using the Preview mode.

How do I access the instructor preview mode of lessons in order to follow the Activity Walk-throughs?

Access the student experience using the Learnspace and the instructor mode using the Workspace (select the Module and lesson to view, then click **Preview Lesson**). Please see the Inspark Instructor FAQs document for more details.

Unit 1 Biology Bootcamp: Scientific Reasoning

Lesson Stats

- Average time spent: 1-1.5 hours

Learning Objectives

- See Instructor's Guide

Assessment

Max score: 243

Lesson Flow

- What is Science? What do scientists do?, Screens 2-3.
- Making audio and visual observations, Screens 6-9.
- Comparing observations and confirmation bias, Screens 10-13.
- Countering Bias: Objectivity and Peer Review, Screens 14-18.
- Instrumental Error, Screens 19-26.
- Measurement Error: Accuracy and Precision, Screens 27-34.
- Designing experiments and the scientific method, Screens 36-44.
- What is a scientific theory? What is a scientific law?, Screens 45-50.
- Introduce experiment topic: Carl and his grades, Screen 52.
- Establish experimental variables and formulate hypothesis, Screens 53-61.

Common Student Issues/Misconceptions

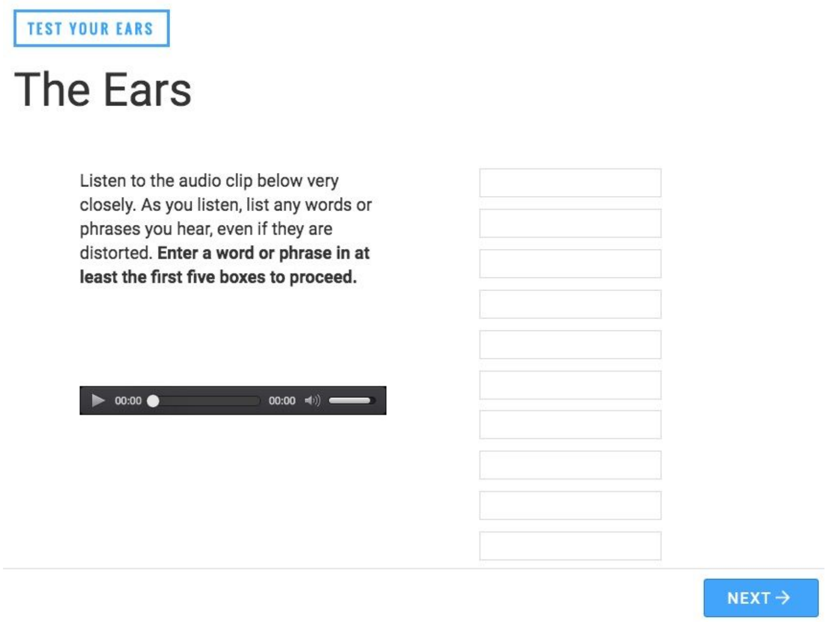
- The primary goal of this lesson is for the student to learn how to harness their observational skills and practice the scientific method. Students will realize that their own subjectivity and bias influences what they observe and how they interpret data.
- Understanding the difference between the independent and dependant variables is key to formulating a good working hypothesis and understanding why certain variables are held constant.

Simulations

There is no simulation in this lesson.

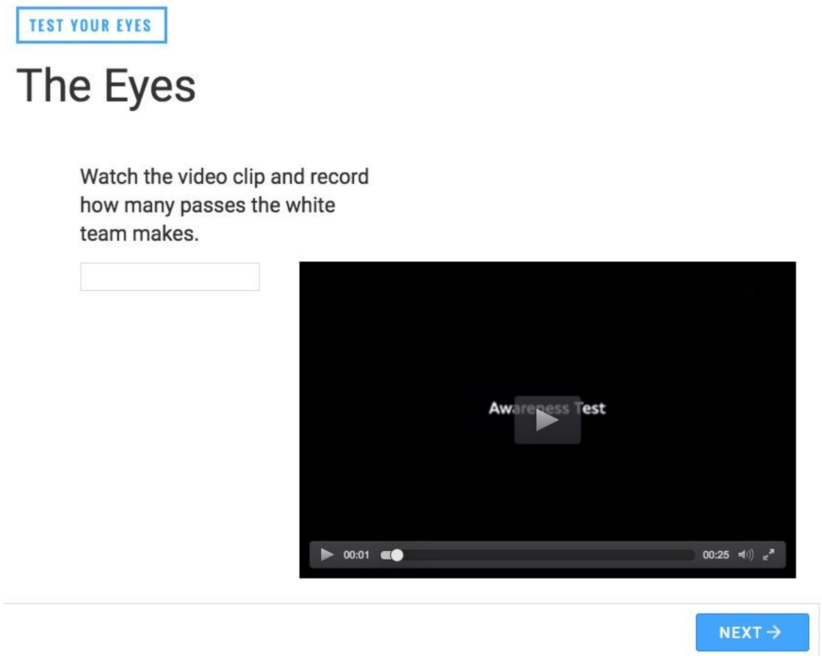
Activity Walk-through

1) Test Your Ears - Listen to audio file (Screens 6-7)



Students are asked to listen to the audio clip in full and write down the words or phrases they hear in at least five of the text boxes to the right. The student must make sure to listen to the entire file the first time around.

2) Test Your Eyes - Watch the video (Screens 8-9)



Students are to watch the short video and pay attention to how many passes the white team makes. Commonly, by paying attention to the passes the student misses other key events in the video i.e. a dancing "bear".

3) Looking at Error - Instrumental Error (Screen 22)

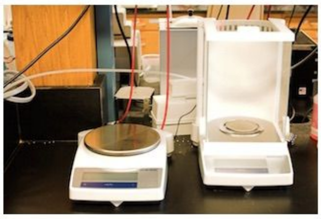
LOOKING AT ERROR

Instrumental Error

You've seen that both balances had significant differences from the 250.0g actual mass, even though the mass didn't change between experiments. These differences are called error, measurement error, or instrumental error, and every instrument has them.

Knowing now that every instrument has some sort of error, which balance would you prefer to use to measure with?

- Balance 1, its variation was more predictable
- Balance 1, its readings were closer to the actual mass
- Balance 1, its difference between readings was smaller
- Balance 1, it read the correct mass each time
- Balance 2, its variation was more predictable
- Balance 2, its readings were closer to the actual mass



Click the links below to view t... again:

NEXT →

Students compare the data they collected from the two measuring instruments and determine which data set is more reliable and what kind of error affects each.

4) Accuracy and Precision (Screens 27-34)

Accuracy and Precision

Another way of thinking about error in measurement is two often used terms: accuracy and precision.

An **accurate** measurement is one which is very close to the actual or accepted value of the measurement.

A **precise** measurement is one which is very close to other measurements made of the same object.

Balance 1	Balance 2
249 g	253.135 g
247 g	253.131 g
250 g	253.133 g
253 g	253.130 g
251 g	253.132 g
249 g	253.130 g
248 g	253.131 g
251 g	253.136 g
250 g	253.133 g

Which balance was more accurate?

- Balance 1 - Balance 2 - Neither

Which balance was more precise?

- Balance 1 - Balance 2 - Neither

NEXT →

In later questions students learn about accuracy and precision and consider how their data reflects these terms.

5) What is the Scientific Method?

Experimental Design

With error and bias skewing your observations and data at every turn, you'll need a way of designing experiments and accounting for the untrustworthy nature of your instruments, both mechanical and biological. This is the oft-referred to **scientific method.**

Often reduced to a poster in classrooms with a set of steps to follow, like the one shown at right, the **scientific method of inquiry** is actually a way to reduce the amount of uncertainty about a problem rather than a set of steps to follow blindly.

Hypothesis: Definition

Good hypotheses propose explanations and predict outcomes of experiments based on prior, often limited, knowledge. Hypotheses can also be described as assumption-driven informed predictions. Which of the options below would therefore be a good hypothesis for an experiment seeking to determine what color of light plants grow best under, knowing that light is necessary and that there is a difference in how they grow depending on color of light?

- ◯ Plants have green pigments, so they should grow best under green light
- ◯ Plants reflect green light, so they should grow best under all light but green
- ◯ Plants will grow the same under all lights
- ◯ Plants are green
- ◯ Plants don't need light to grow

Students are introduced to the Scientific Method and provided a expanded definition of a hypothesis. This is the scaffold upon which students will practice their critical thinking skills and reference as a guide for the next slides in the lesson.

6) Make Your Own Experiment

INTRODUCTION TO THE EXPERIMENT

Beginning the Experiment

What areas do you see in Carl's habits that might be good targets to change in order to help his grades? **Select all that apply:**

- ☐ Commute time
- ☐ Study time
- ☐ Sleep time
- ☐ Extracurricular Activities (Maker Club)
- ☐ Choice of hobby
- ☐ Type of car
- ☐ Carl's grades
- ☐ Classes Carl is taking
- ☐ Diet

Here the student will start their own experiment and will hypothesize which of Carl's habits should be changed in order to improve his grades.

Unit 1 Biology Bootcamp: Scientific Tools

Lesson Stats

- Average time spent: 2 hours

Learning Objectives

- See Instructor's Guide

Assessment:

Max score: 285

Lesson Flow:

- Introduction, Screens 1-2.
- Measurement, Screens 3-13.
- SI Units, Screens 14-22.
- Cubic Units, Screens 23-28.
- Dimensional Analysis, Screens 29-38.
- SI Prefixes, Screens 39-41.
- Scientific Notation, Screens 42-45.
- Models (Modeling), Screens 46-55.
- Helping Carl, Screens 56-60.
- Models (Models in Science), Screens 61-63.

Common Student Issues/Misconceptions

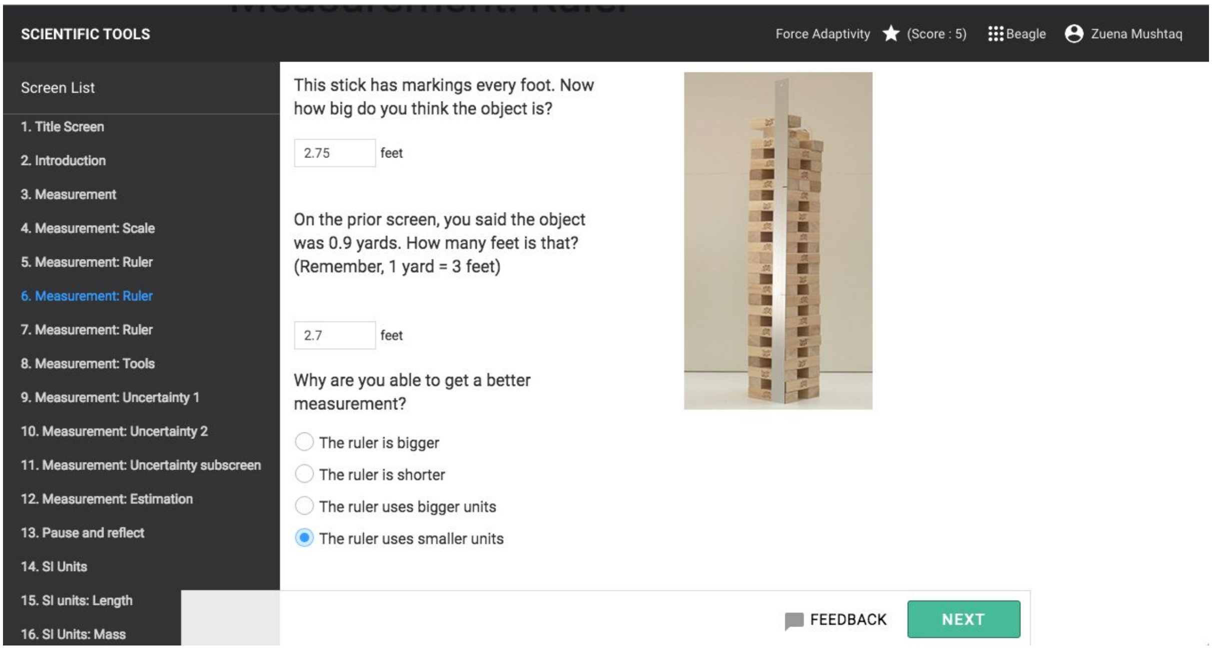
- Students can get very caught up in the minute details during measurements and end up getting the answer wrong (ultimately, they were being too precise). If this happens, let the student know that they have made it more complicated than necessary and to try again without thinking too hard about it.

Simulations

There is no simulation in this lesson.

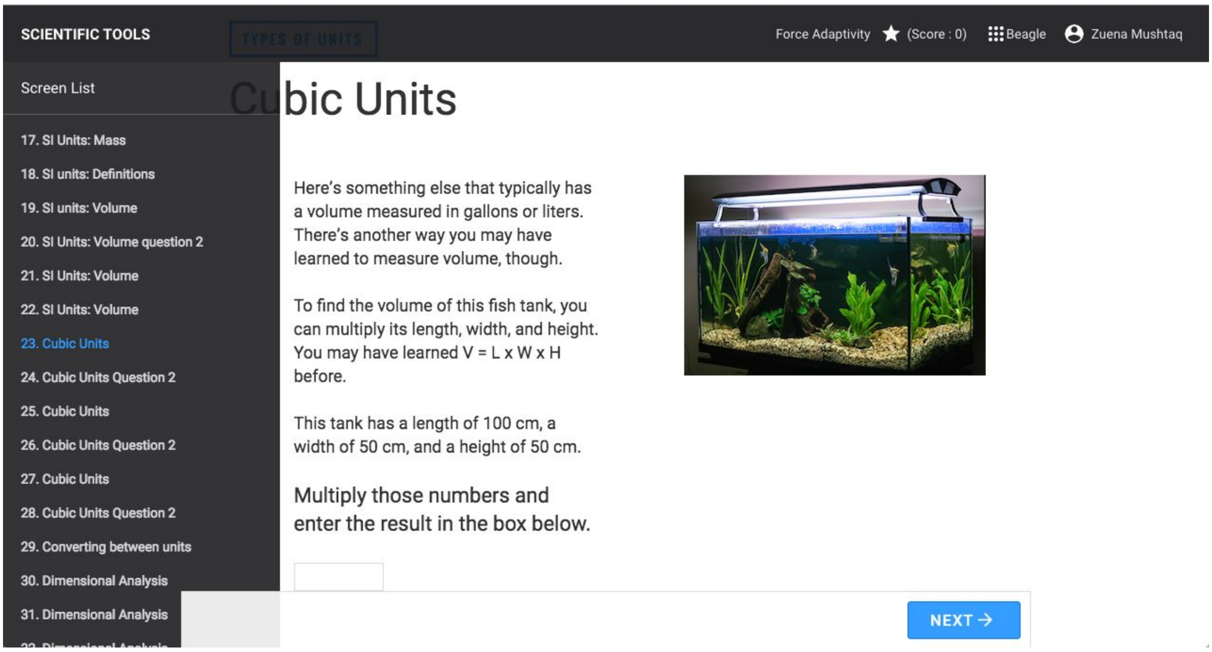
Activity Walk-through

1) Measurement: Ruler (Screen 6)



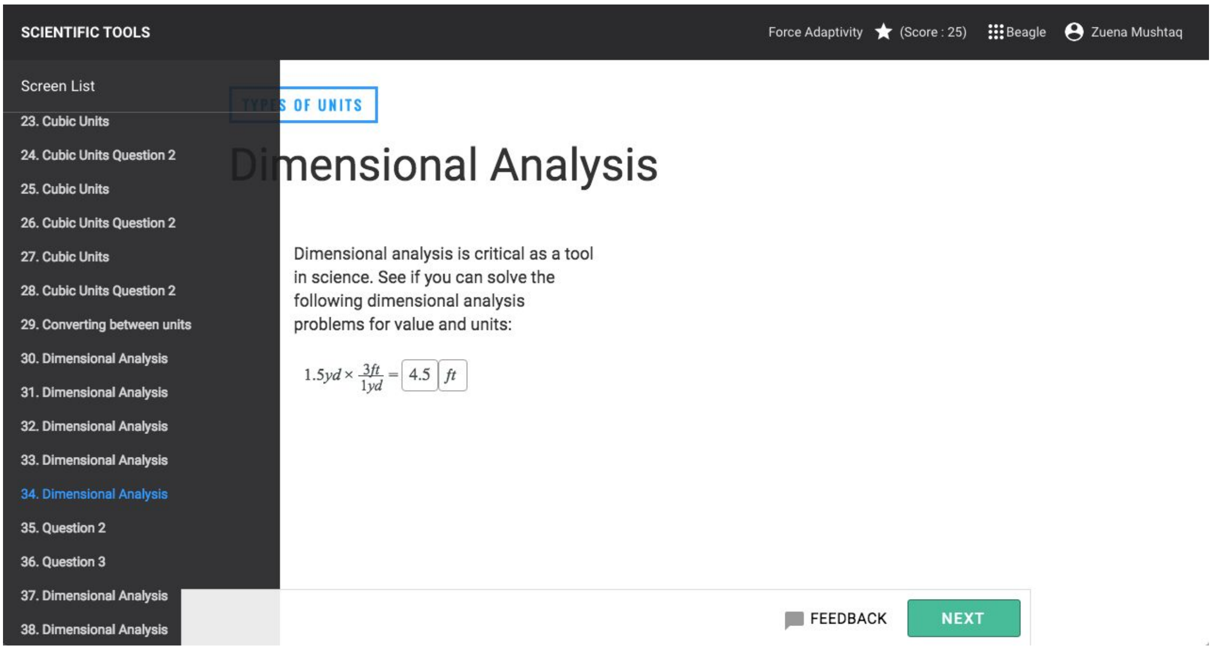
As mentioned in the common misconceptions section, students tend to get too precise when estimating the length of the tower in these lessons. It's important for them to understand that estimations are just that - estimations. It's ok to not be precise. This will help them understand the importance of precision using smaller units.

2) Cubic units (Screen 23)



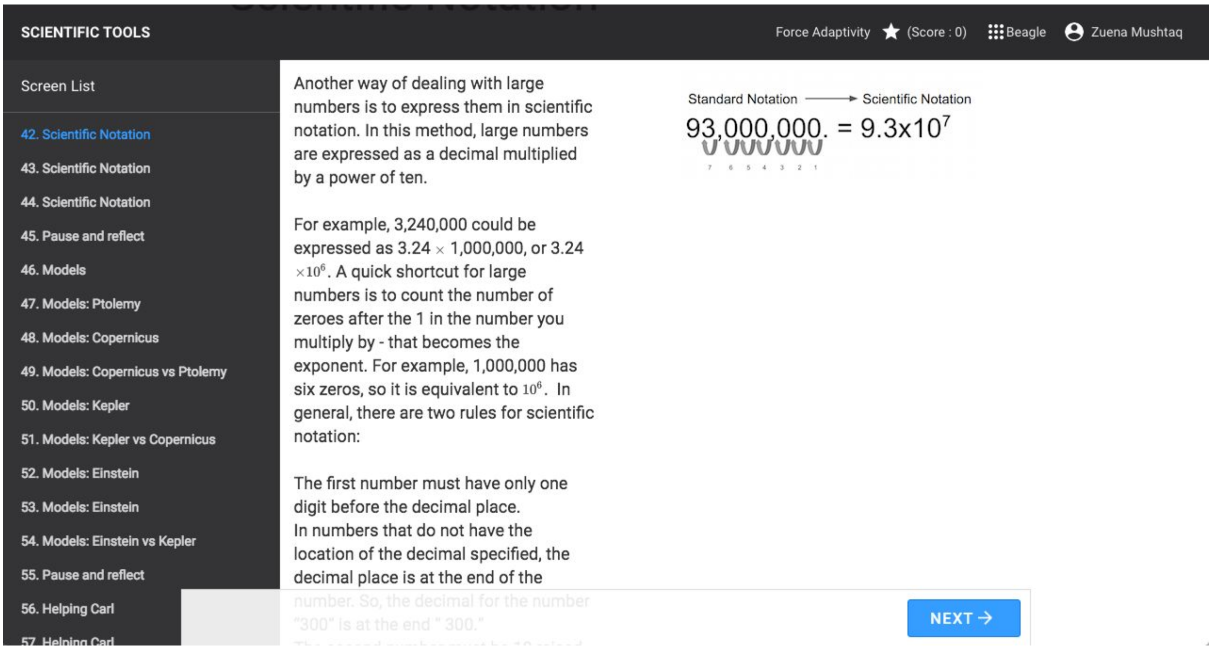
This screen is very important as it teaches the basis of cubic units and how to determine the volume of an object. Students need to understand how to calculate the volume of a cube (ie. a tank in this situation) in order to work through the other screens in this lesson.

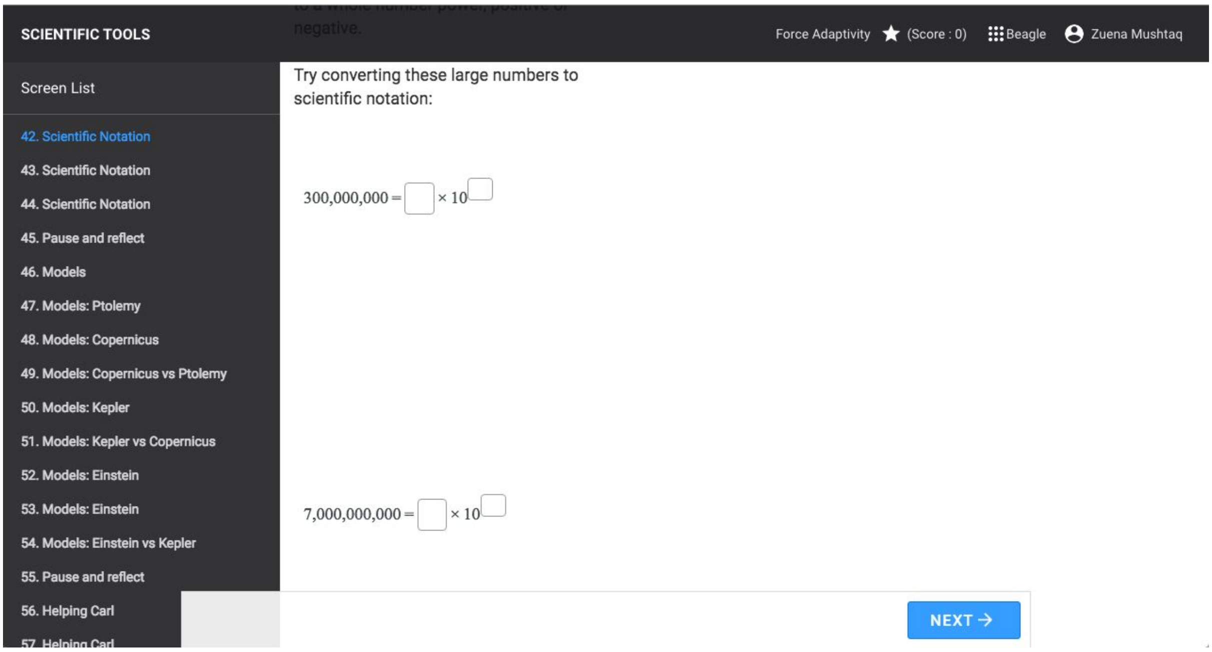
3) Dimensional Analysis (Screen 34)



Students need to understand dimensional analysis in order to move forward with the rest of the lesson. This screen does a great job of building upon previous screens and explaining what dimensional analysis truly is using simple concepts. Students need to understand the basis of dimensional analysis in order to work the rest of the problems in this lesson.

4. Scientific Notation (Screen 42)





Scientific notation, and converting to scientific notation, is explained on this screen. Furthermore, students are expected to actually convert numbers into scientific notation as well. This is the foundation for the next screens as students are asked to work through more scientific notation problems.

Unit 1 Biology Bootcamp: Scientific Skills

Lesson Stats
- Average time spent: 45 minutes

Learning Objectives
- See Instructor's Guide

Assessment
Max score: 135

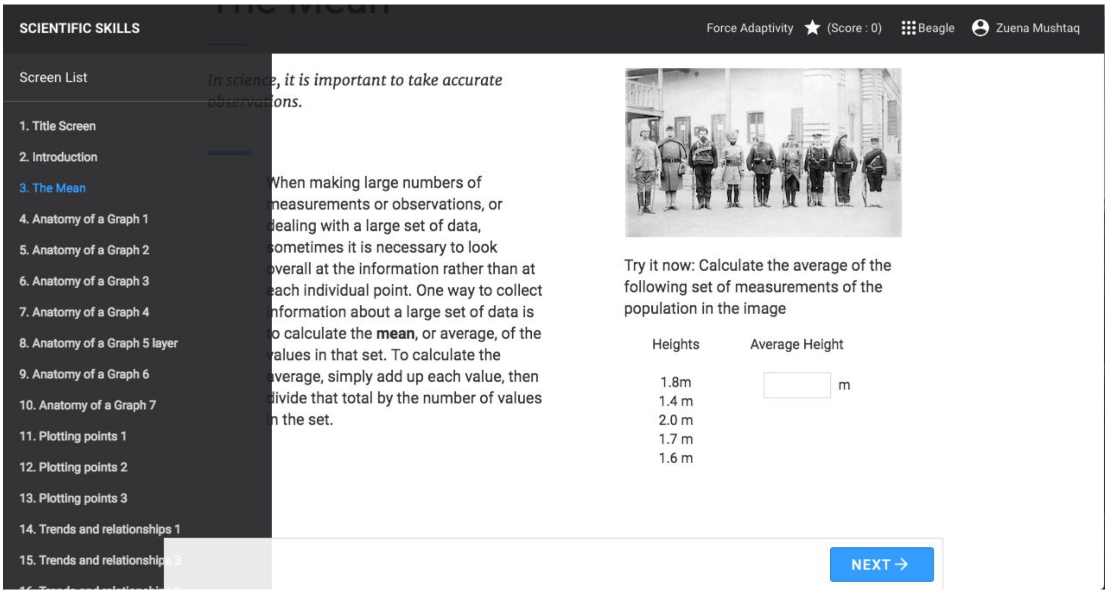
Lesson Flow
- Labelling graphs, Screens 4-10.
- Plotting points on a graph, Screens 11-13.
- Trends and relationships, Screens 14-17.
- Distributions, Screens 19-22.
- The Maker Club, Screens 24-35.
- Carl's commute, Screens 36-43.
- Carl's study habits, Screens 44-52.

Common Student Issues/Misconceptions
- A lot of students had trouble with the graphing portion of The Maker Club Screens because the graphs only go from -10 to 10 on both axes and they did not realize that they can drag the screen to reach numbers beyond -10 and 10.
- On certain browsers the graphs can sometimes not operate correctly and students are unable plot points; if that happens, let the student know that they should logout and log back in and refresh the lesson before starting it again.

Simulations
There is no simulation in this lesson.

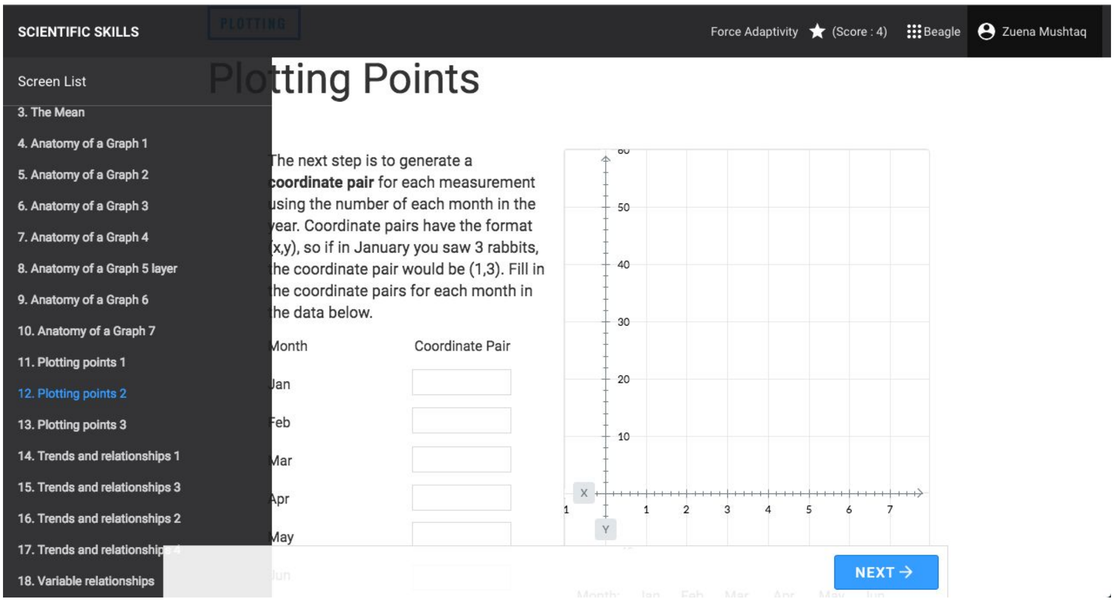
Activity Walk-through

1) The Mean (Screen 2)



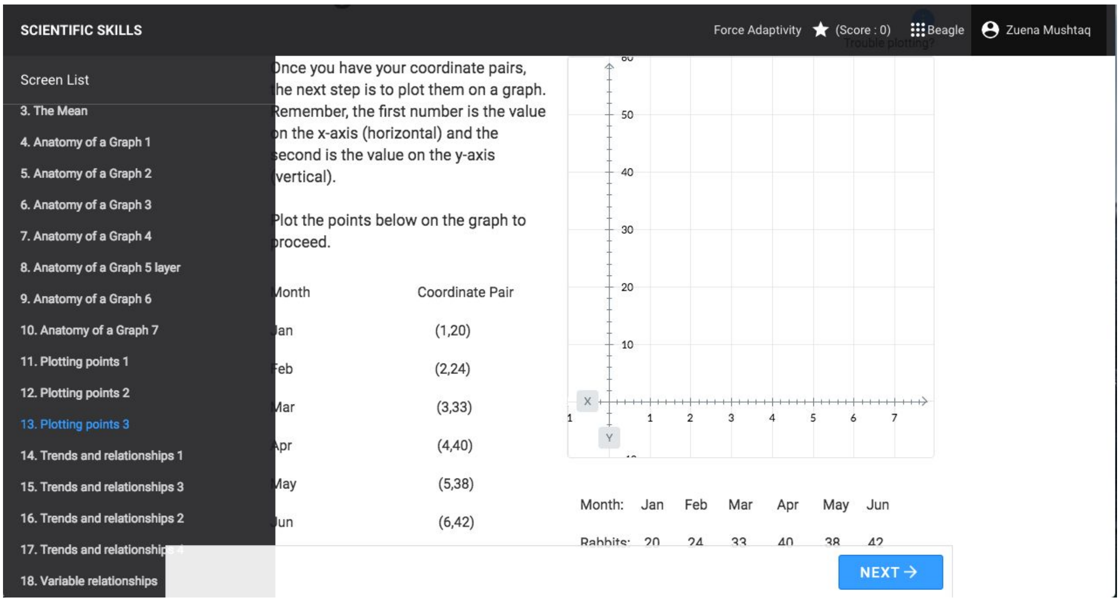
This screen asks students to calculate the mean and is important for students to understand as they will need to be able to calculate the mean for various activities that appear later on in the lesson.

2) Plotting points (Screen 12)



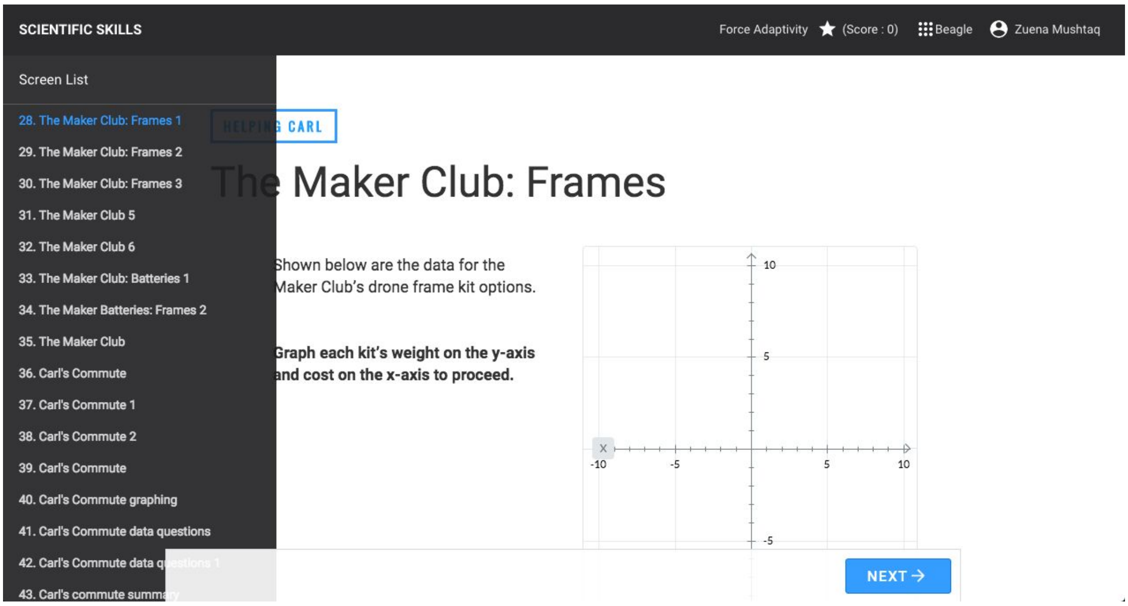
This screen asks students to determine the coordinate pair for each measurement. This is extremely important for students to understand as it is the basis for how to plot points, which they are asked to do later in the lesson.

3) Plotting points (Screen 13)



Students are then asked to plot the points on the graph. This is probably the most important screen in the whole lesson. If students do not understand how to plot coordinate pairs, then they will not understand any of the lessons beyond this.

4) The Maker Club: Frames (Screen 28)



Students are asked to plot the points and will have to create the coordinate pairs by themselves, based on the information that is provided.

Unit 1 Biology Bootcamp: Graphing Skills

Lesson Stats
- Average time spent: 30 minutes

Learning Objectives
- See Instructor's Guide

Assessment

Max score: 0

Lesson Flow
- Introduction, Screens 1-3.
- Anatomy of a Graph, Screens 4-10.
- Plotting Points,Trends, Relationships and Correlations, Screens 14-17.
- Variables, Screens 18.
- Distributions, Screens 19-22.
- Reflection and Summary, Screen 24.

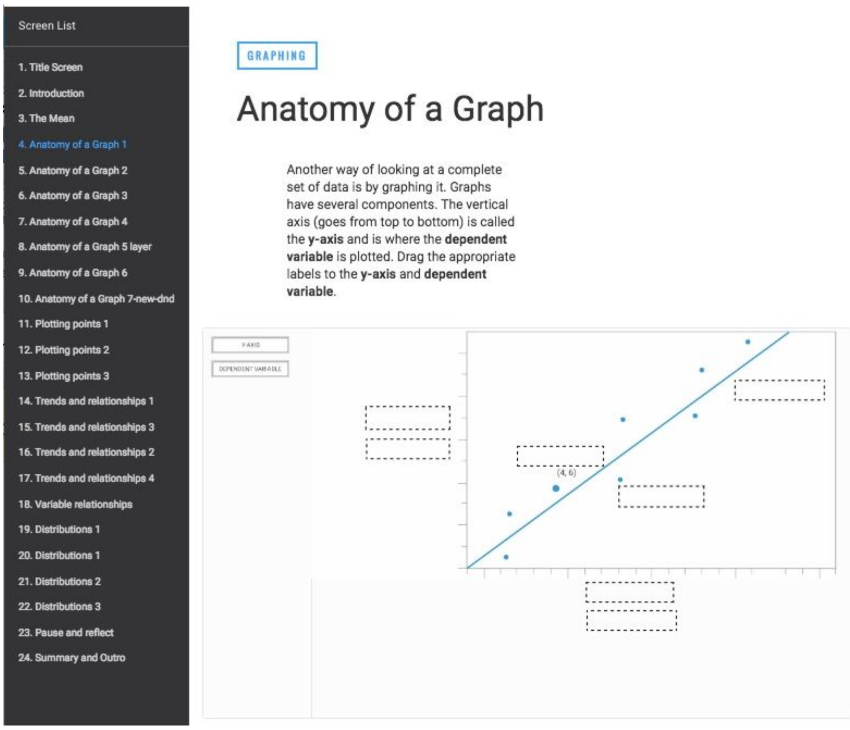
Common Student Issues/Misconceptions
- On certain browsers the graphs can sometimes not operate correctly and students are unable plot points; if that happens, let the student know that they should logout and log back in and refresh the lesson before starting it again.

Simulations

There is no simulation in this lesson.

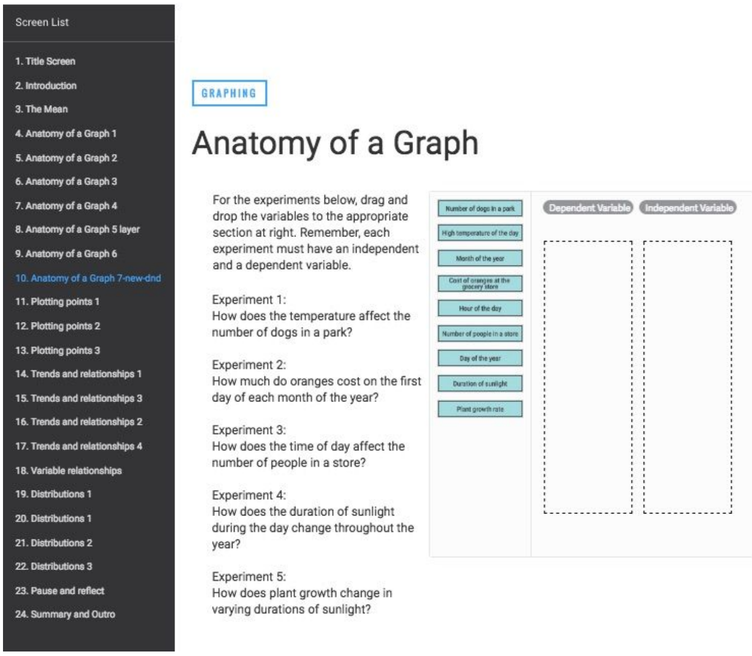
Activity Walk-through

1. Anatomy of a Graph (Screen 4)



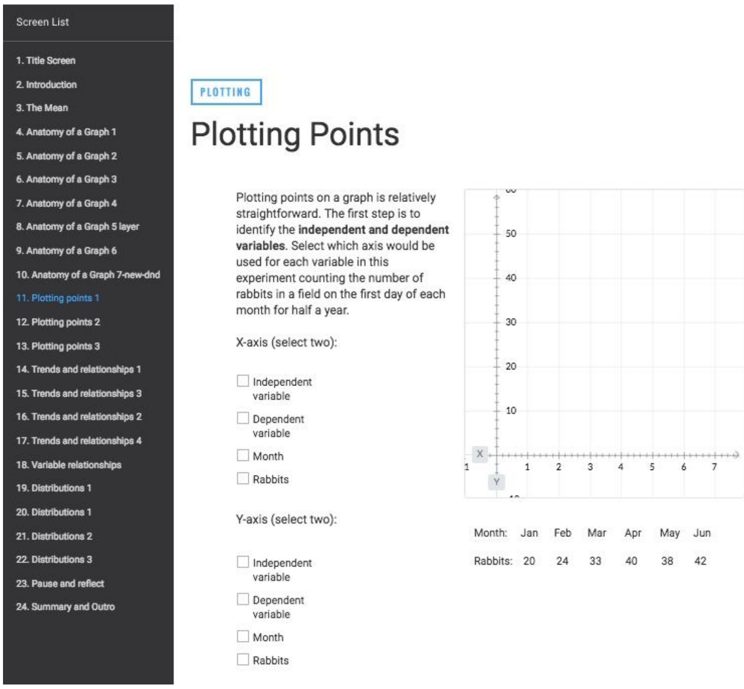
On this screen and the following screens students will become familiar with the different parts of a graph. Understanding the x-axis, y-axis, independent variable, dependent variable, and trend line is critical for maximizing student understanding for the rest of the lesson.

2. Anatomy of a Graph - Independent and Dependent Variable (Screen 10)



On this screen students are given a number in which they are to sort the respective independent and dependent variable.

3. Practice Plotting (Screen 11)



On this screen and the following screens students are to determine the independent and dependent variable and practice plotting points.

Unit 2 World Biodiversity Exploration: Sonoran Desert

Lesson Stats

- Average time spent: 1.5 hours

Learning Objectives

- See Instructor's Guide

Assessment

Max score: None – please read below for more clarification regarding scoring for this unit.

- This lesson serves as a tutorial for the entire unit and has 10 organisms students have to find and observe that are added to their classification project.
- Points are awarded based on the quality of the observations made. This lesson is critical for completion of this unit and scoring is entirely based on the Classification Project.
- In total, there are 60 organisms in the entire unit, and students are required to observe at least a total of 50 across all of the lessons in this unit.
- 40% of the total score is based on the quality of observations made and the other 60% is based on how students group their organisms during the My Classification project.

Lesson Flow

- Introduction, Screen 1.
- How to scan and find organisms, Screens 2-5.
- Using Observer and determining how to make good observations, Screens 7-17.
- Learn to Classify, Screen 26. Students will be automatically sent to the How to Classify lesson and back according to the following flow:
    - After they've made observations of 3 different organisms in the Sonoran Desert, they will go to How to Classify.
    - Students are shown how to use the classifier, then practice classifying the three organisms they have observations for in their observer.
    - Students are sent back to the Sonoran Desert to make observations of two more organisms.
    - Students are sent back to How to Classify to learn more about what makes a good classification and add the additional two organisms to their classification.
    - Students are sent back to the Sonoran Desert to find and complete making observations of the remaining five organisms.

Important note: Students start making their classification in How to Classify, but will later finish it in the My Classification lesson. All classification work the students do will be saved across the How to Classify and My Classification lessons.

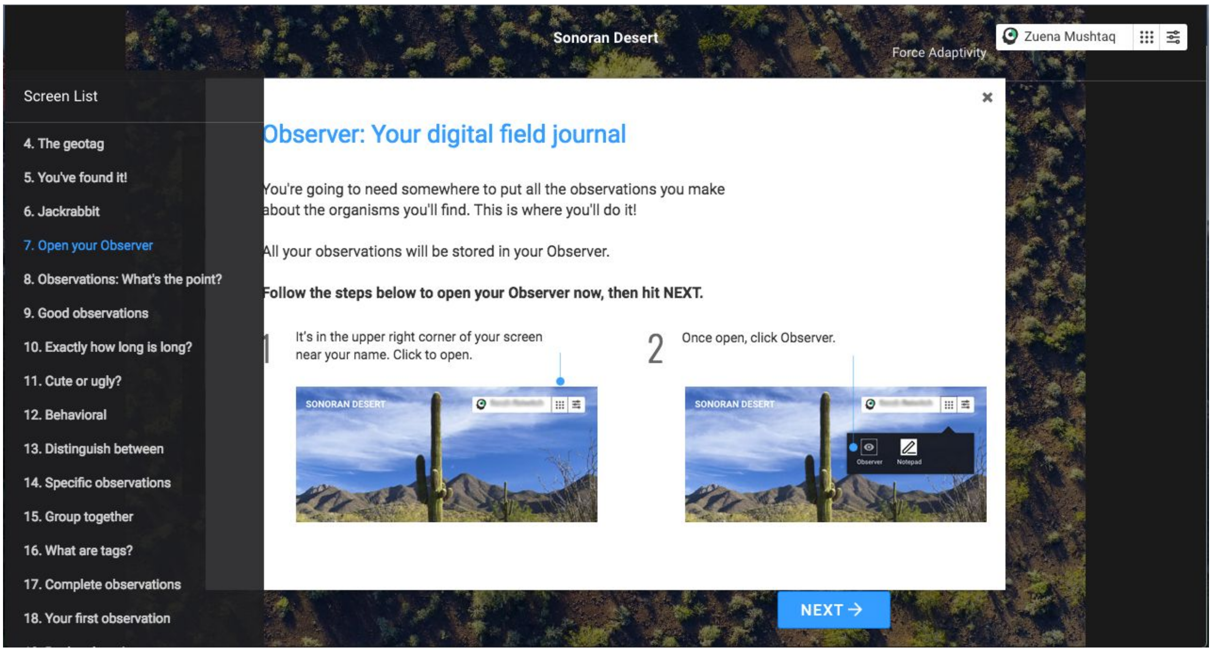
Common Student Issues/Misconceptions

- At the beginning of their observation and classification journey, students get really caught up on what makes a good observation vs. what makes a bad observation and they make it a lot harder than it needs to be. A lot of students also may get frustrated when they make an observation and it is not accepted because it does not meet the criterion that has been set forth. In these situations, it is important to reiterate that they need to make sure that they have made correct observations, in accordance with what they have been taught in the lesson.

Simulations
There is no simulation in this lesson.

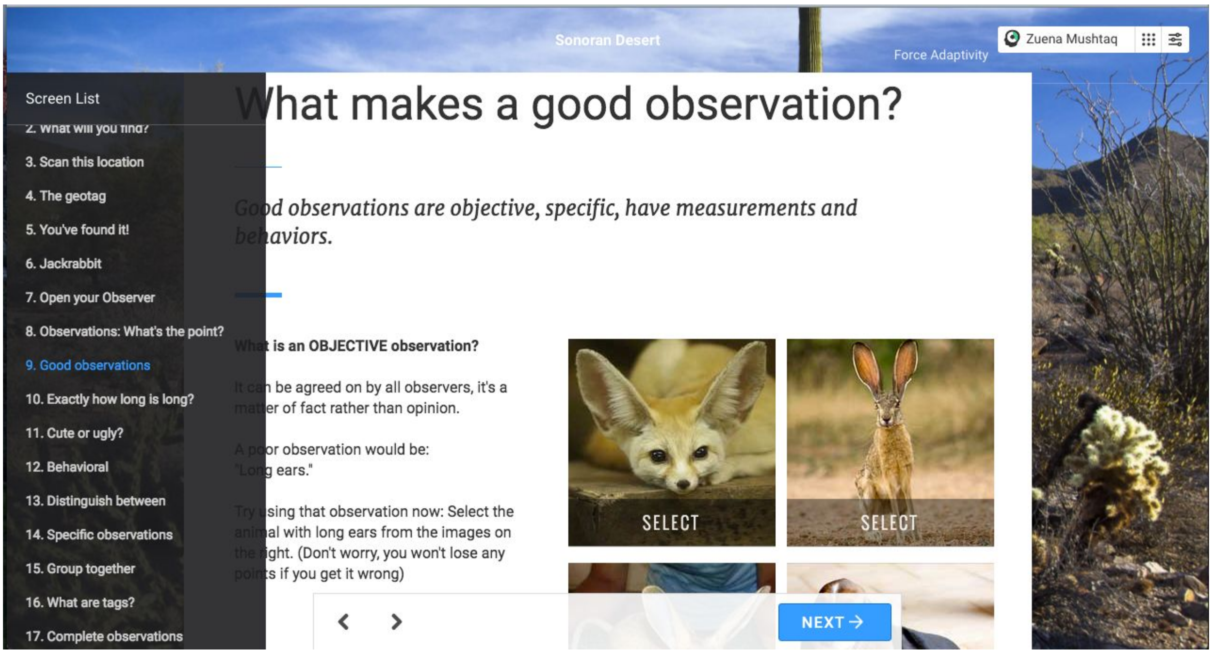
Activity Walk-through

1) Open your observer (Screen 7)



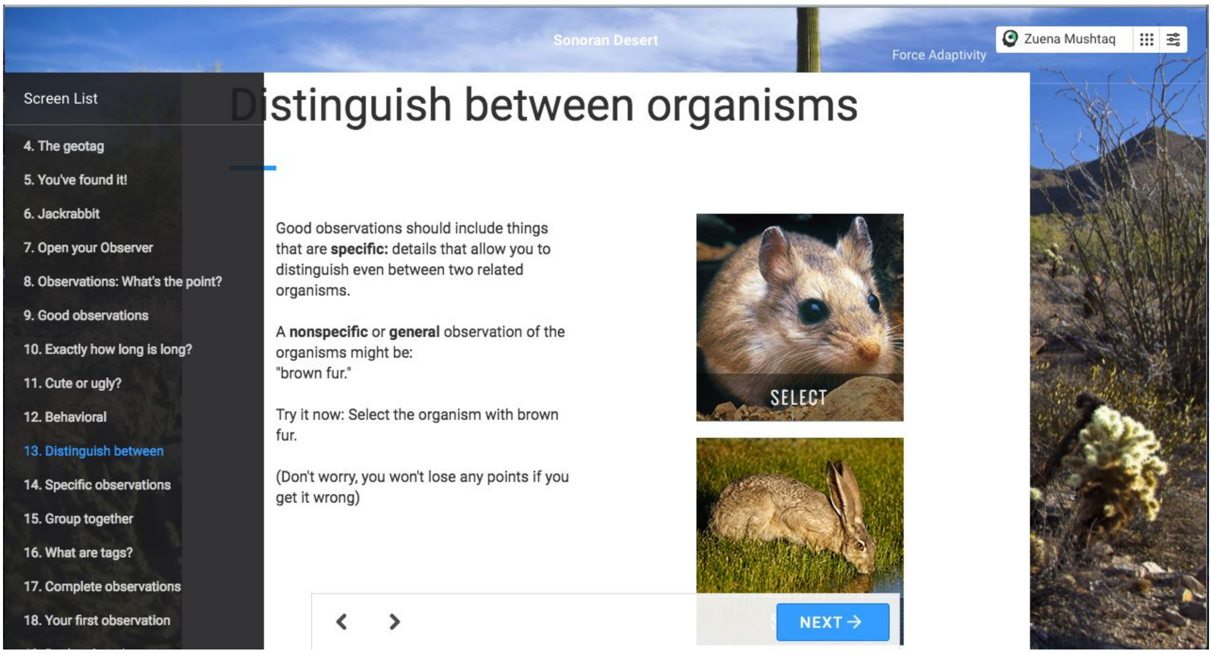
Students will be making observations using the Observer so it is imperative that they understand how to open this widget and how to also use it.

2) Good Observations (Screen 9)



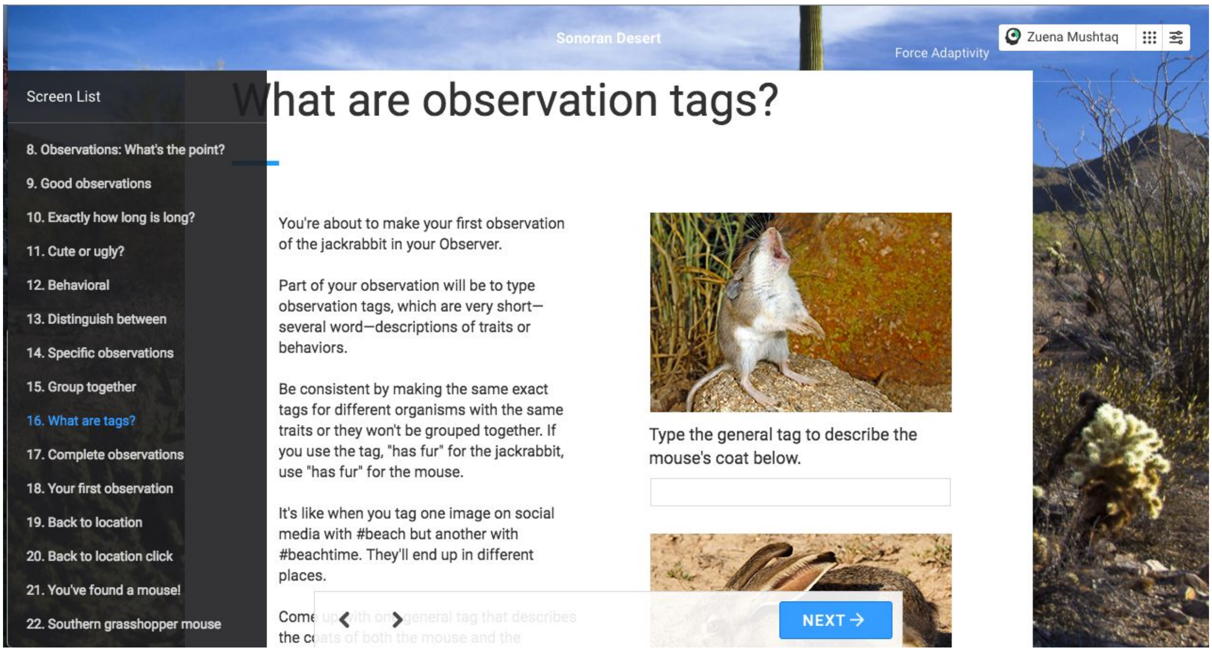
This screen helps students begin to understand the importance behind observations and how to make GOOD observations accordingly. This sets up the scene for all of the biodiversity lessons. Good observations are an integral part of science and if students are unable to make such observations when finding various organisms, then they will not be able to move on with the lesson.

3) Distinguish between organisms (Screen 13)



This screen reinforces the importance of making specific observations, as opposed to general ones. Students need to understand how specific observations can make a huge difference when trying to classify and group the organisms that they have found accordingly.

4) What are tags? (Screen 16)



Along with observing organisms and keeping track of them, students will also be asked to create tags. Each organism they observe will require 5 tags (except for the first organism, the Black-tailed jackrabbit, which requires 6) that they will have to input themselves. This screen helps them understand how to make tags and what makes a good tag and what makes a bad tag. These tags will be used later on to classify the organisms that they will have observed.

Unit 2 World Biodiversity Exploration: How to Classify

Lesson Stats

- Average time spent: 1 hour

Learning Objectives

- See Instructor's Guide

Assessment

- 40% of the total score for the unit is based on the quality of observations made and the other 60% is based on how students group their organisms during classification in the My Classification lesson. This is the project for the entire unit. Students must work on their classification here and hit “FINISH” to have their scores to register in the learnspace.

Lesson Flow

- Students are directed here automatically from the Sonoran Desert lesson after they’ve made observations of 3 different organisms.
- Students are shown how to use the classifier, then practice classifying the three organisms they have observations for in their observer.
- Students are sent back to the Sonoran Desert to make observations of two more organisms.
- Students are sent back to How to Classify to learn more about what makes a good classification and add the additional two organisms to their classification.
- Students are sent back to the Sonoran Desert to find and complete making observations of the remaining five organisms.

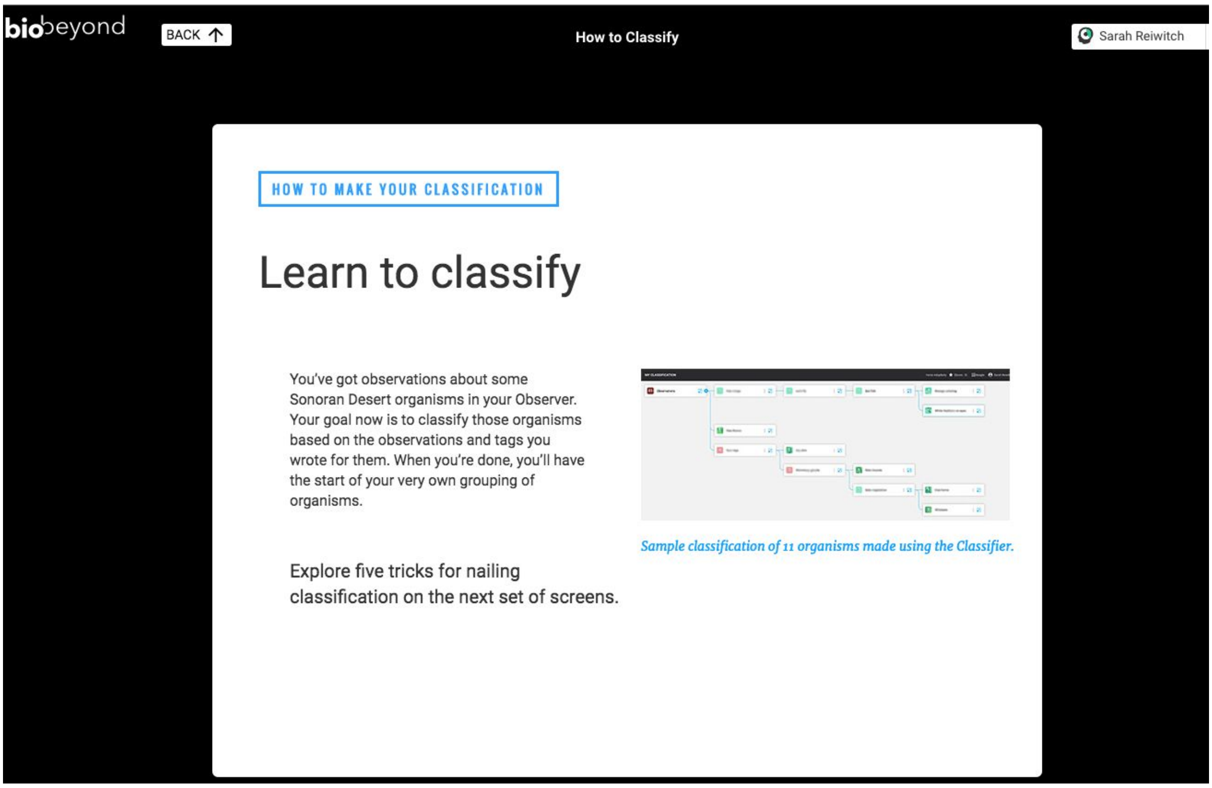
Common Student Issues/Misconceptions

- Coming soon

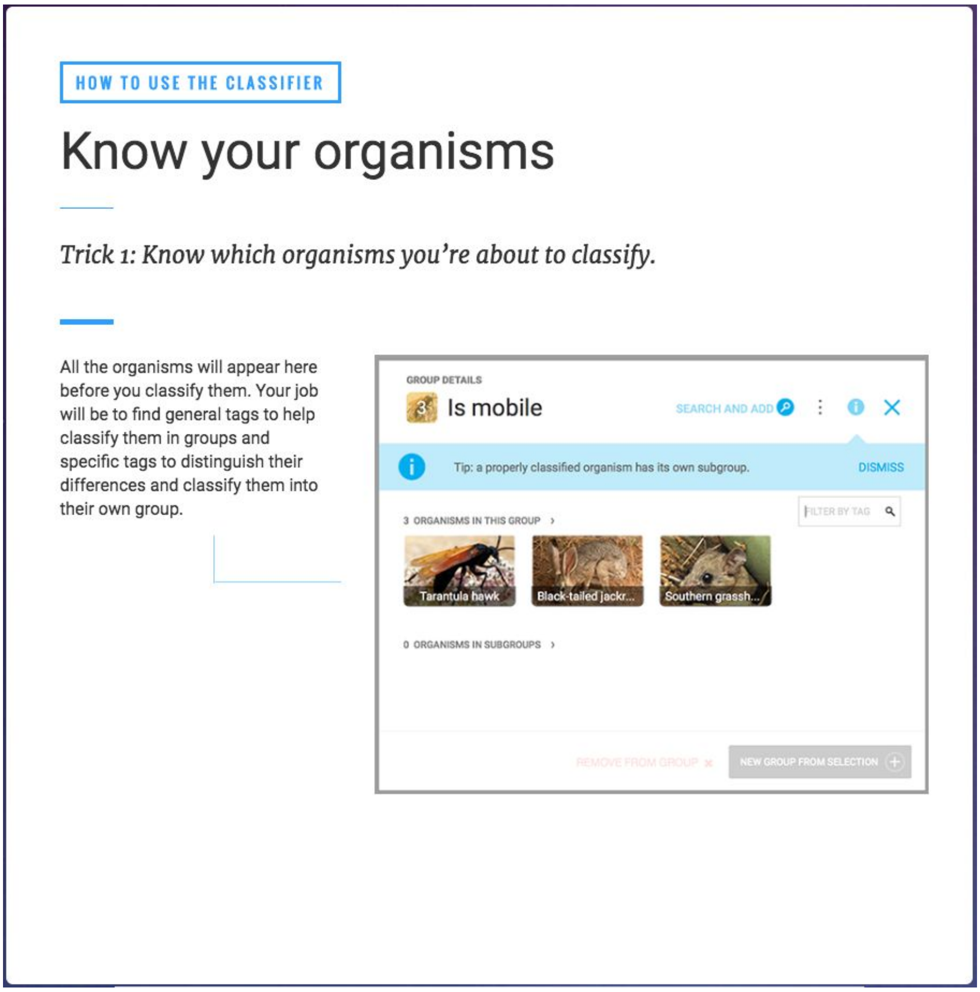
Simulations

There is no simulation in this lesson.

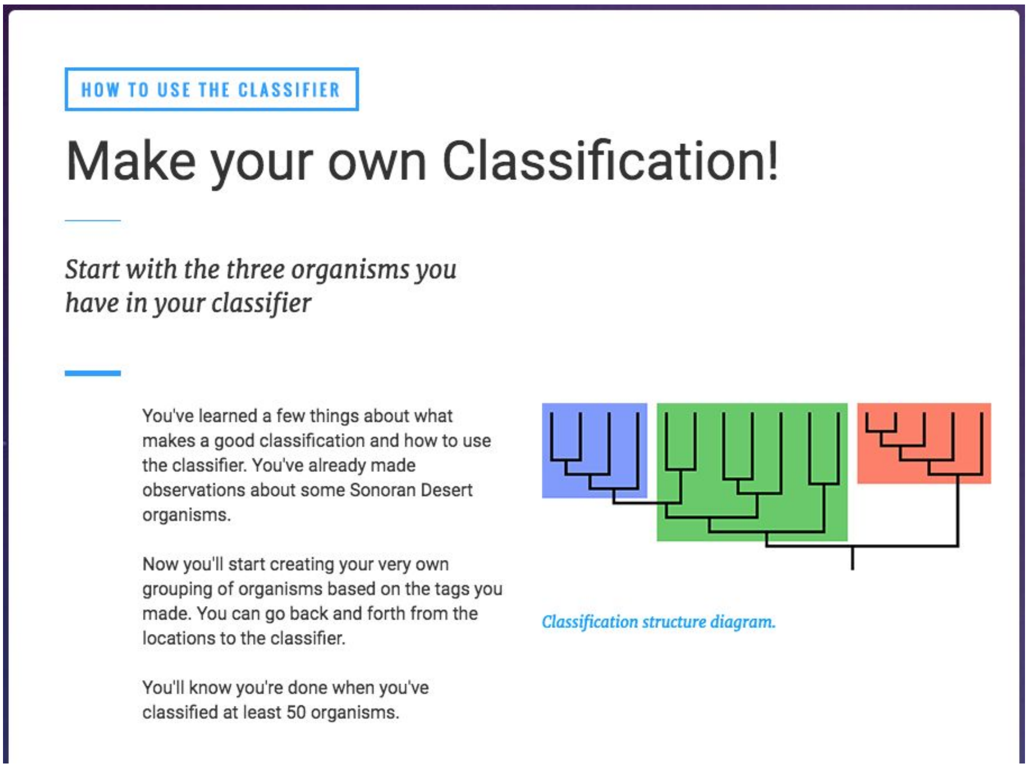
Activity Walk-through

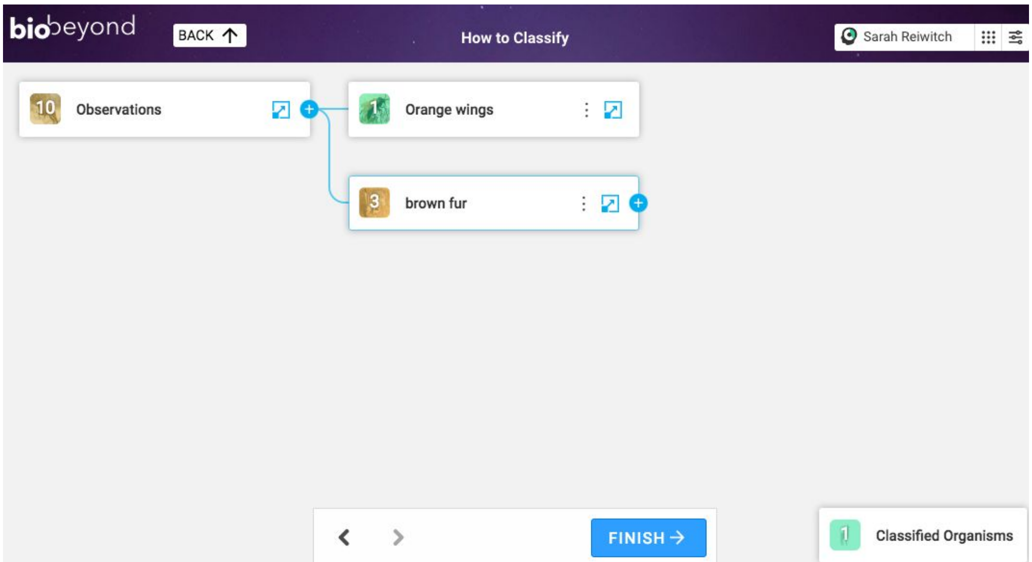


This screen is very important as it begins to teach students the importance of classification and how they will be expected to classify the organisms that they will be making observations about. A sample showing how classification *should* look is also provided to show students how these classifications should be made.



This screen explains how classifications would be made using the tags that students generate during their observations of organisms.





This screen leads the student into making their own classification so that they understand the method behind how this will need to be done in the rest of the lessons in this unit.

Unit 2 World Biodiversity Exploration: Deep Ocean Floor

Lesson Stats

- Average time spent: 1 hour

Learning Objectives

- See Instructor's Guide

Assessment

Max score: None - please read below for more clarification regarding scoring for this unit.

- Points are awarded based on the quality of the observations made. This lesson is critical for completion of this unit and the Classification Project.
- This lesson has 9 organisms that students have to find and observe.
- In total, there are 60 organisms within this entire unit, and students are required to observe at least a total of 50 across all of the lessons in this unit.
- 40% of the total score is based on the quality of observations made and the other 60% is based on how students group their organisms during classification in the My Classification lesson. This is the project for the entire unit. Students must work on their classification here and hit “FINISH” to have their scores to register in the learnspace.

Lesson Flow

- Students select a location to be taken to classify some organisms, Screens 1-3.
- Various Organisms, Screens 4-12.

Common Student Issues/Misconceptions

- Coming soon

Simulations

There is no simulation in this lesson.

Activity Walk-through

None. Students continue what they began in Sonoran Desert, except now they are on the Ocean Floor. Students continue to make observations of organisms that they find.

Unit 2 World Biodiversity Exploration: Antarctica

Lesson Stats
- Average time spent: 1 hour

Learning Objectives
- See Instructor's Guide

Assessment
Max score: None - please read below for more clarification regarding scoring for this unit.
- Points are awarded based on the quality of the observations made. This lesson is critical for completion of this unit and the Classification Project.
- This lesson has 10 organisms that students have to find and observe.
- In total, there are 60 organisms within this entire unit, and students are required to observe at least a total of 50 across all of the lessons in this unit.
- 40% of the total score is based on the quality of observations made and the other 60% is based on how students group their organisms during classification in the My Classification lesson. This is the project for the entire unit. Students must work on their classification here and hit “FINISH” to have their scores to register in the learnspace.

Lesson Flow
- Location, Screens 1-3.
- Various Organisms, Screens 4-13.

Common Student Issues/Misconceptions
- None

Simulations
None

Activity Walk-through
None. Students continue what they began in Sonoran Desert, except now they are in Antarctica. Students continue to make observations of organisms that they find.

Unit 2 World Biodiversity Exploration: Yellowstone National Park

Lesson Stats

- Average time spent: 1 hour

Learning Objectives

- See Instructor's Guide

Assessment

Max score: None - please read below for more clarification regarding scoring for this unit.

- Points are awarded based on the quality of the observations made. This lesson is critical for completion of this unit and the Classification Project.
- This lesson has 11 organisms that students have to find and observe.
- In total, there are 60 organisms within this entire unit, and students are required to observe at least a total of 50 across all of the lessons in this unit.
- 40% of the total score is based on the quality of observations made and the other 60% is based on how students group their organisms during classification. Student score is registered for the student only after they work in the My Classification (project) lesson and hit "FINISH."

Lesson Flow

- Location, Screens 1-3.
- Various Organisms, Screens 4-14.

Common Student Issues/Misconceptions

- None

Simulations

None

Activity Walk-through

None. Students continue what they began in Sonoran Desert, except now they are in Yellowstone National Park. Students continue to make observations of organisms that they find.

Unit 2 World Biodiversity Exploration: New York City

Lesson Stats
- Average time spent: 1 hour

Learning Objectives
- See Instructor's Guide

Assessment
Max score: None - please read below for more clarification regarding scoring for this unit.
- Points are awarded based on the quality of the observations made. This lesson is critical for completion of this unit and the Classification Project.
- This lesson has 10 organisms that students have to find and observe.
- In total, there are 60 organisms within this entire unit, and students are required to observe at least a total of 50 across all of the lessons in this unit.
- 40% of the total score is based on the quality of observations made and the other 60% is based on how students group their organisms during classification in the My Classification lesson. This is the project for the entire unit. Students must work on their classification here and hit “FINISH” to have their scores to register in the learnspace.

Lesson Flow
- Location, Screens 1-3.
- Various Organisms, Screens 4-13.

Common Student Issues/Misconceptions
- None

Simulations
None

Activity Walk-through
None. Students continue what they began in Sonoran Desert, except now they are in New York City. Students continue to make observations of organisms that they find.

Unit 2 World Biodiversity Exploration: Great Barrier Reef

Lesson Stats

- Average time spent: 1 hour

Learning Objectives

- See Instructor's Guide

Assessment

Max score: None - please read below for more clarification regarding scoring for this unit.

- Points are awarded based on the quality of the observations made. This lesson is critical for completion of this unit and the Classification Project.
- This lesson has 10 organisms that students have to find and observe.
- In total, there are 60 organisms within this entire unit, and students are required to observe at least a total of 50 across all of the lessons in this unit.
- 40% of the total score is based on the quality of observations made and the other 60% is based on how students group their organisms during classification in the My Classification lesson. This is the project for the entire unit. Students must work on their classification here and hit "FINISH" to have their scores to register in the learnspace.

Lesson Flow

- Location, Screens 1-3.
- Various Organisms, Screens 4-13.

Common Student Issues/Misconceptions

- None

Simulations

None

Activity Walk-through

None. Students continue what they began in Sonoran Desert, except now they are in the Great Barrier Reef. Students continue to make observations of organisms that they find.

Unit 2 World Biodiversity Exploration: My Classification (Project)

Lesson Stats

- Average time spent: 1-2 hours

Learning Objectives

- See Instructor's Guide

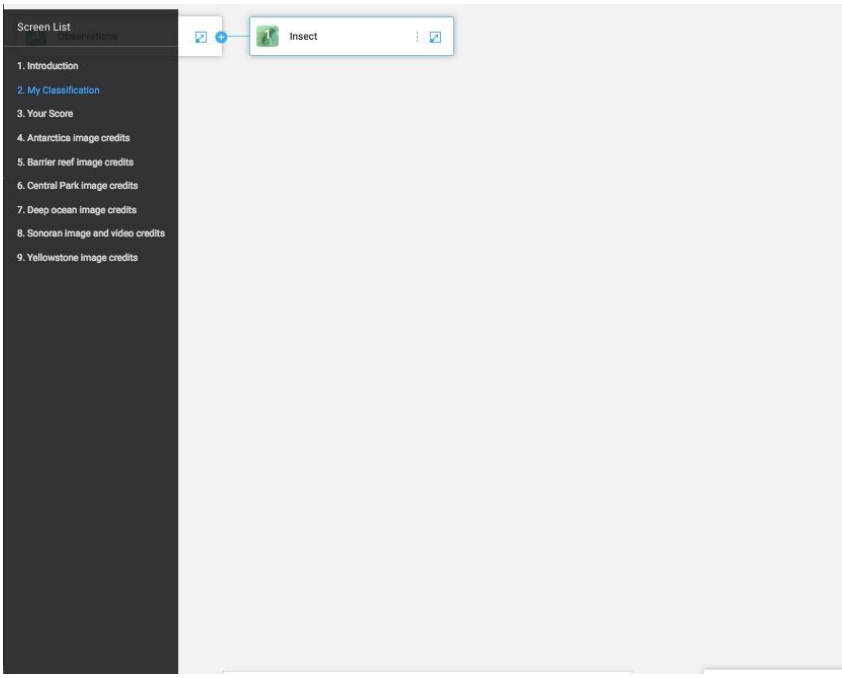
Assessment

Max score: 1000 - please read below for more clarification regarding scoring for this unit.

- In total, there are 60 organisms within this entire unit, and students are required to observe at least a total of 50 across all of the lessons in this unit.
- 40% of the total score is based on the quality of observations made and the other 60% is based on how students group their organisms during classification. This is the lesson where the score will be recorded. The classification that was started in How to Classify will be saved in the in My Classification lesson. Students will need to complete their classification in My Classification and hit "FINISH" for the score to be recorded to the learnspace.

Activity Walk-through

1. Continued Classification (Screen 2)



This is where students can continue to work on their classification. They can access it at any time after they've completed the Sonoran Desert and How to Classify. It's where they'll get their score recorded to the learnspace so they'll need to hit "FINISH" in this lesson for that to happen.

Unit 3 Journey to the Galapagos: Why You Look the Way You Do?

Lesson Stats

- Average time spent: 1.5–2.5 hours

Learning Objectives

- See Instructor's Guide

Assessment

Max Score: 160

Lesson Flow

- The Traits in You, Screens 6-9.
- Case Studies: Observing Traits in Couples, Screens 10-16.
- Gregor Mendel's Experiment, Screens 17-21.
- Pause and Reflect, Screen 22.
- Gregor Mendel Experiment F2, Screens 23-26.
- Dominant and Recessive Traits, Screens 27-31.
- Trait Variations, Screens 32-37.
- Pause and Reflect 2, Screen 38.
- Law of Segregation, Screens 39-41.
- Law of Independent Assortment, 42-47.
- Pause and Reflect 3, Screen 48.
- Summary, Screen 49.

Common Student Issues/Misconceptions

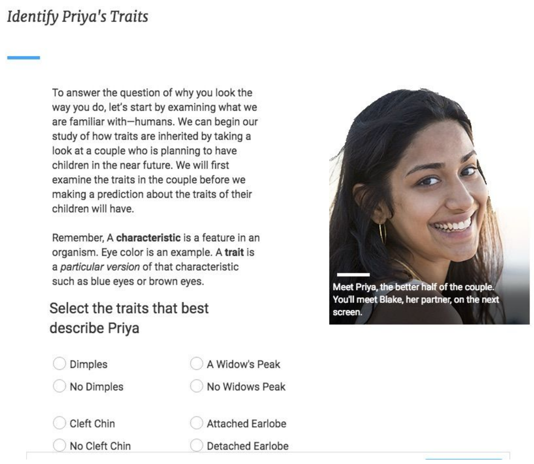
- Students sometimes have trouble distinguishing between the modes of recessive and dominant inheritance. The laws of segregation and independent assortment are also sometimes confused by students who are unfamiliar with genetics.

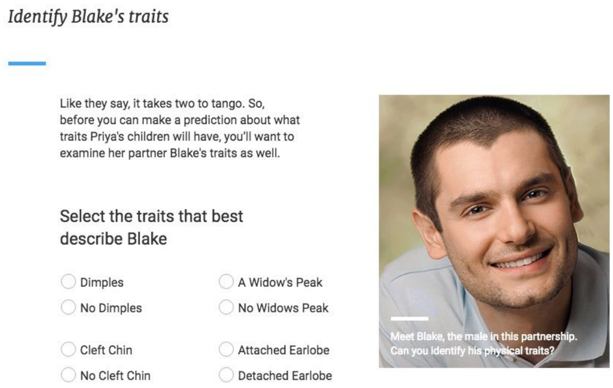
Simulations

There is no simulation in this lesson.

Activity Walk-through

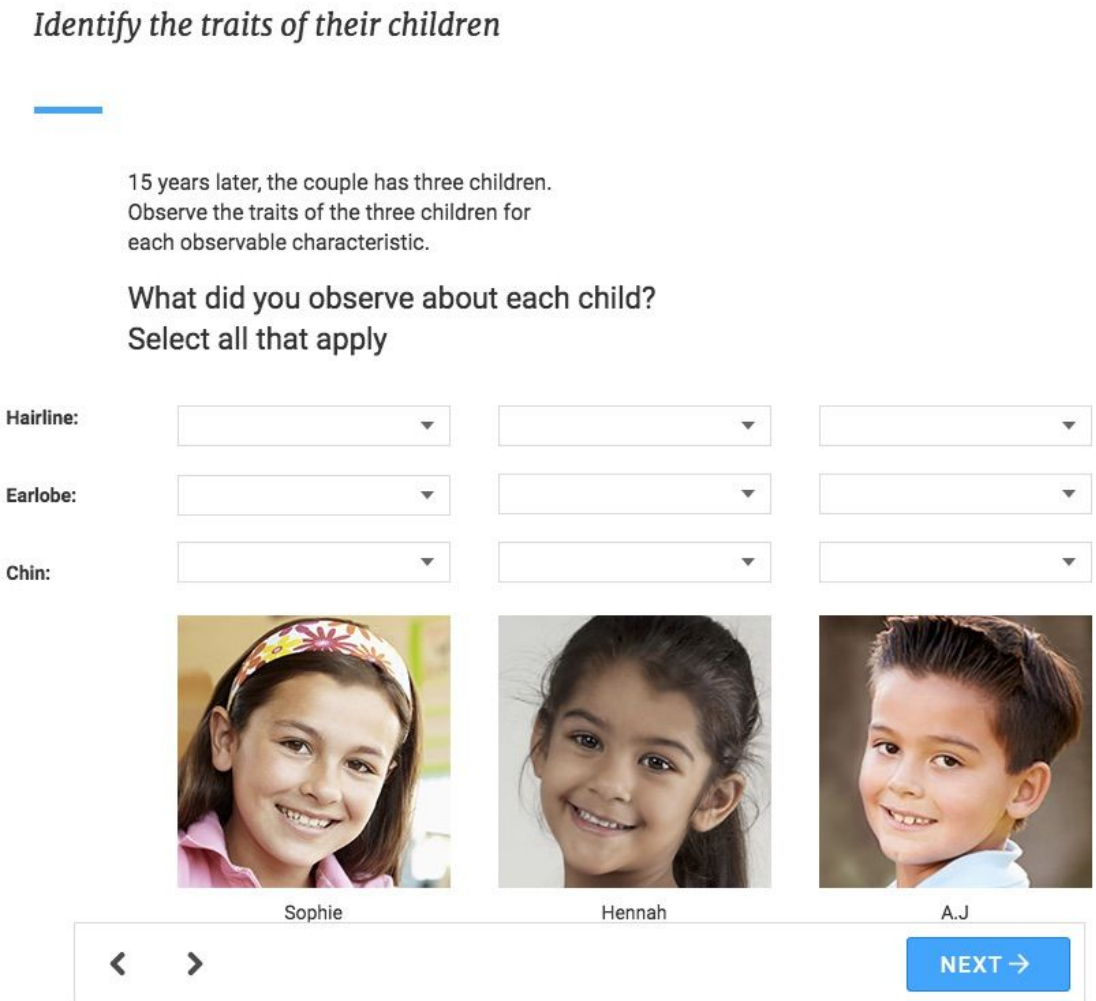
1) Traits in a Couple - Priya and Blake (Screen 7 & 8)





Students are asked to observe and select the traits that Priya and Blake express. This is their introduction to the concept of inheritance.

2) Traits in Priya and Blake's Children (Screen 10)



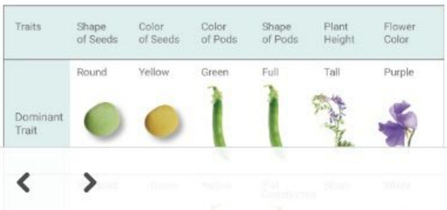
The concept of this page is identical to the previous one, except now it is the children's traits that are being recorded.

3) Gregor Mendel's First Experiment (Screen 15)

Why Pea Plants?

What made Pea Plants a suitable plant for Mendel's experiments?

Part of what made pea plants a good choice for Mendel's experiment was the fact that they had traits that could be easily identified. The difference between a white flower and a red flower, for example, may be easier to spot than perhaps a cleft chin. With pea plants, Mendel could control which plants mated with each other. Pea plants also grow easily and mature quickly which allowed Mendel to conduct more experiments in a far shorter time.



Traits	Shape of Seeds	Color of Seeds	Color of Pods	Shape of Pods	Plant Height	Flower Color
Dominant Trait	Round	Yellow	Green	Full	Tall	Purple

Why did Mendel choose to grow pea plants for his experiment? Select all that apply

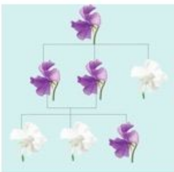
- ☐ They were the only plant that could grow in the garden.
- ☐ They grow and mature quickly.
- ☐ They provide food for other organisms.
- ☐ Their traits are easily noticeable.
- ☐ They can withstand harsh environments.

NEXT →

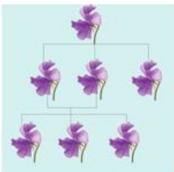
How do you select plants that are purebred?

To find out what happened when Mendel crossed purebred purple-flowered and a white-flowered pea plants, you're going to need to recreate that cross. But how do you know if a plant is purebred, exactly? To prevent any other unwanted traits from appearing in later generations, we want to find true breeding purple-flowered and white-flowered pea plants to cross. An organism with a true breeding trait is one whose ancestors (and offspring) all had/have that same trait.

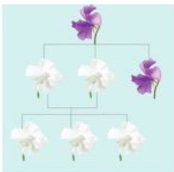
Select two family trees: one that represents purebred white pea plants AND one that represents purebred purple-flowered plants.

☐ 

1. Impure white-flowered plant.

☐ 

2. Pure purple-flowered plant.

☐ 

3. Impure purple-flowered plant.

☐ 

4. Pure white-flowered plant.

4) Dominant vs. Recessive Traits

To understand dominant vs. recessive traits, you have to first be able to identify traits in an organism.

Identify the coat color trait for the dog above:

- ◯ Brown Coat ◯ Yellow Coat
- ◯ Black Coat

Identify the coat color trait for the dog above:

- ◯ Brown Coat ◯ Yellow Coat
- ◯ Black Coat

5) Homozygous and Heterozygous Traits

There are two genotypes: Homozygous and Heterozygous

Can you sort the homozygous genotypes from the heterozygous ones?

The organisms you have seen so far had only one type of allele in their genotype. For example "TT" (both the letter "T" and both capitalized). An organism with a genotype containing only one type of allele is said to be **homozygous** (*homo*=same).On the contrary, an individual with two different alleles for a trait such as "Tt" is said to be heterozygous.

	Homozygous	Heterozygous
RR		
rr		
tT		
pp		
PP		
Tt		
TT		

NEXT →

6) Inheriting Multiple Traits

Inheriting Multiple Traits

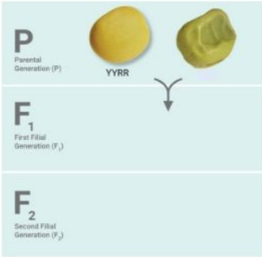
Organims have more than one trait, How are multiple traits passed down?

By uncovering the law of segregation, Mendel figured that just because a parent had a genotype such as "Pp", didn't mean that its offspring had to inherit that same combination of alleles. Now, he wanted to know if a plant with two traits (such as yellow seeds and a round seed-shape) could pass down *one* as opposed to *both* of their traits to their offspring. In other words, he wanted to know if the many different traits in a parent were tied together--forcing offspring to inherit a "package" with all of that parent's traits. Cross two plants—each with two different purebred traits, to find out.

LEGEND

Y = yellow pods

y = green pods



A purebred Round-Yellow-seeded pea plant will have a genotype of YYRR.

What will be the genotype of the purebred wrinkled green-seeded pea plant?

1:

Unit 3 Journey to the Galapagos: Disease Detectives

Lesson Stats

- Average time spent: 1.5–2.5 hours

Learning Objectives

- See Instructor's Guide

Assessment

Max score: 226

Lesson Flow

- Introduction: Your Mission, Screens 1-9
- Basics: Genotypes and Phenotypes, Screens 10-16
- Punnett Squares: Predicting Genotypes and Phenotypes, Screens 16-28
- Double Traits Crosses, Screens 29-35
- Pedigrees, Screens 36-39
- Hemophilia, Screens 37-45
- Blood Typing, Screens 46-58
- Application to Disease: Sickle Cell, Screens 59-69
- Reevaluating Mendel: Screen 70
- Pause and Reflect, Screen 71
- Summary, Screen 72

Common Student Issues/Misconceptions

- Students may sometimes have a difficult time understanding the difference between a phenotype and a genotype, especially at points in the lesson where there are sex-linked trait and codominance.
- Students may find it difficult determining what phenotype an individual will express in a double testcross.

Simulations

There is no simulation in this lesson.

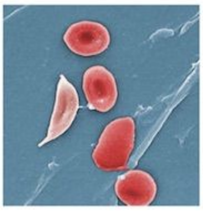
Activity Walk-through

1) Your Challenge (Screen 5)

Your Challenge

Great to have you on board! Welcome to the clinic. Things are a little crazy over here right now. But there's a lot for you to do before you get started.

Choose what you'd like to do next.

MEET JAMAL	JAMAL'S CONDITION	MY MISSION?
		

Students are tasked with helping to find a good blood sample for Jamal who suffers from sickle cell anemia. Throughout the lesson students learn about inheritance broadly and apply their knowledge to Jamal's case.

2) Genotype (Screen 11)

What is a Genotype?

Learn about the code scientists use to talk about traits

Classify the following genotypes as homozygous or heterozygous:

"P" and "p" are examples of two *different* alleles. Their different cases (uppercase and lowercase) tell that they code for two different traits.

In order to predict the outcome of a genetic cross, you need to know the alleles of each parent. According to Mendel, each person contains two alleles for any given trait. The combination of alleles in an organism is known as the ***genotype.*** For example, TT is a genotype for a purebred tall plant. Each "T" in this genotype is an allele, or genetic factor that was inherited from a parent.

Organisms with two of the *same* alleles for a trait are called **homozygous**.

Organisms with two *different* alleles for a trait are called **heterozygous**.

Homozygous

Heterozygous

HH

hh

Hh

What is the Phenotype?

What other information can we get from the genetic code or genotype?

How an organism looks is typically determined by it's genotype or genetic code. In the case of a heterozygous genotype, where an organism has two *different* alleles (such as Tt), what appearance, or ***phenotype***, does it take on? According to Mendel, the organism will resemble the dominant allele.

- **Dominant alleles** are represented by capital letters.("G "for example, is a dominant allele for the green pod trait)
- **Recessive alleles** (lowercase letters) are not expressed when paired with dominant

LEGEND

G = Green Pods

g = Yellow Pods

Select the correct phenotype (appearance) for the following genotypes:

Students are tasked with sorting different allele combinations into homozygous and heterozygous categories Understanding genotype and phenotype is foundational to the rest of the lesson especially as the concepts of dominance, recessiveness and co-dominance are introduced.

3) Offspring Genotype and Phenotype (Screen 15)

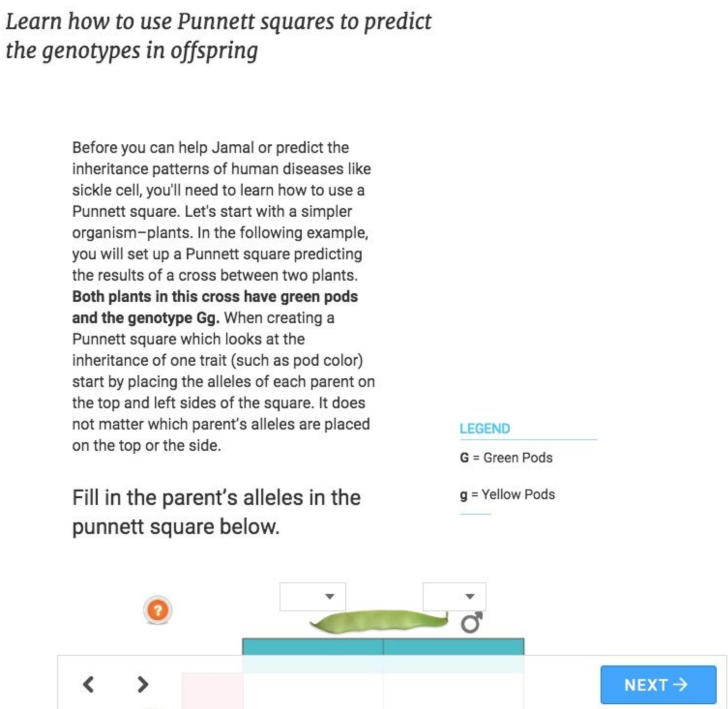
Can you predict the genetic code and appearence of the offspring?

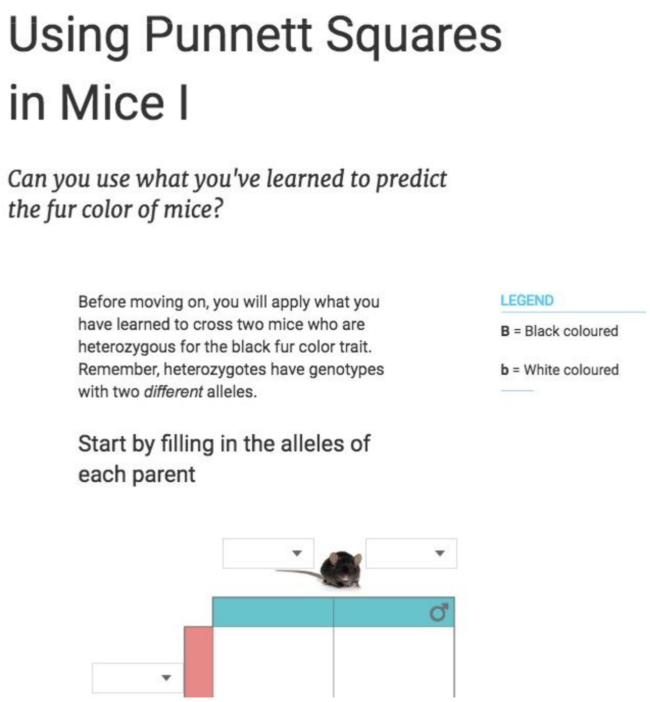
Look at the sex cells of the tall and short plants. An offspring forms from the combination of two sex cells–one from each parent. Since each sex cell of a parent contains one allele for a trait, offspring will have a genotype with two alleles.

To predict the outcome of a cross, remember that the genotype for any child is composed of one allele from the mother and one allele from the father. One of the parent plants is homozygous for the tall trait (TT) and the other parent is homozygous for the short trait (tt). Predict the outcome in the children.

Here students apply the information they learned on the previous screens and apply the concept of genotype and phenotype to a plant cell.

4) Creating Punnett Squares (Screen 17)





Here students will further explore the concept of genotype as expressed in plants and animals with the help of punnett squares. Students will begin notice that that heterozygous genotypes are always expressed the same way, despite having alleles for two different traits. These screens will make students take notice how certain alleles are overshadowed by others, ultimately introducing them to the concept of dominance.

5) Punnett Square with Two Traits (screen 35)

Two-trait Cross

Practice predicting the appearance of organisms from a two-trait Punnett Square

Fill in the missing boxes with with the correct genotype and phenotype for this cross.

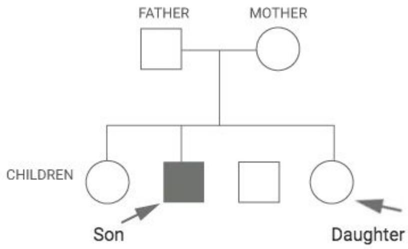
For this activity students will apply their knowledge of punnett squares to explore what offspring result when two cows heterozygous for two different traits (BbPp) are mated together. This activity requires attention, as distinguishing the potential phenotypes can be tricky. Students should recall what the parents of the heterozygous cow looked like as a guide.

6) How to Read a Pedigree (screen 36)

What is a Pedigree?

How to trace disease in humans

Now that you understand how to use Punnett squares to predict the chances of inheriting certain traits, you're ready to trace the inheritance patterns of diseases. Unlike plants, scientists cannot purposely select and mate two humans (ethically speaking). Instead, to study how human traits and diseases are inherited, scientists use a chart called a pedigree. A **pedigree** traces the presence of a disease or trait through multiple generations in a family. It not only shows who has a particular trait/disease but also who carries an allele for the disease as well.



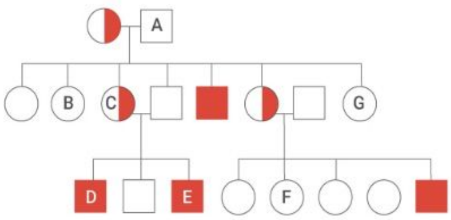
How are males represented in the pedigree?

How are females represented in the pedigree?

The "Royal Disease"- Hemophilia

What pattern of inheritance do you notice for this disease?

In a pedigree, a shaded-in shape represents someone who is "affected" by a disease. Look at this pedigree for the disease, hemophilia. Sometimes known as the "royal disease" because of its prevalence in the royal families of several European nations, those with hemophilia lack a protein that helps clot blood. As a result, severe bleeding can result from a minor injury.



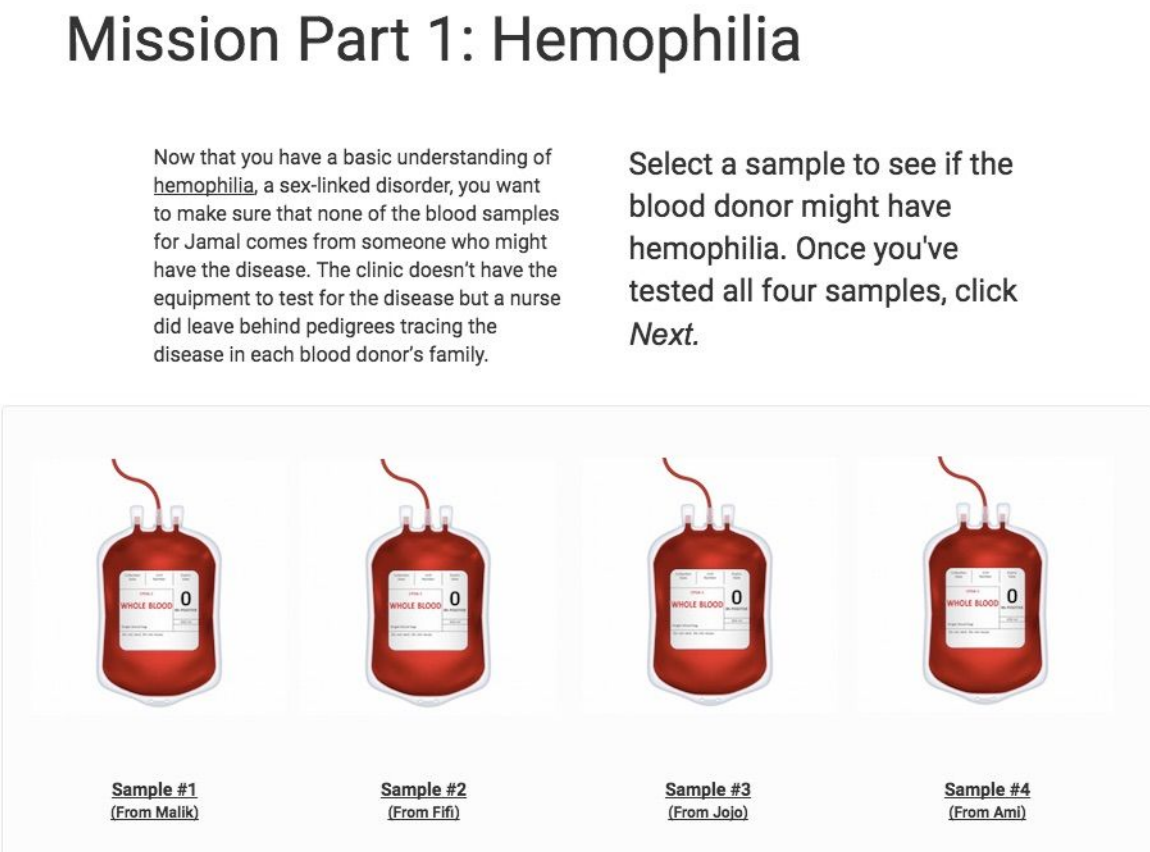
Select the individuals who have hemophilia

☐ A ☐ B ☐ C ☐ D ☐ E ☐ F ☐ G

Which individual (s) do

Here students will learn how to read a pedigree and use it to track the inheritance of particular alleles deleterious to health. The pedigree helps students visualize patterns of inheritance in a small population. In the next screen it is applied to Hemophillia, a recessive x-chromosome linked condition that affects only males. This example shows that inheritance can be more nuanced than just recessive and dominant.

7) Analyzing Blood Type and Hemophilia (Slide 40)

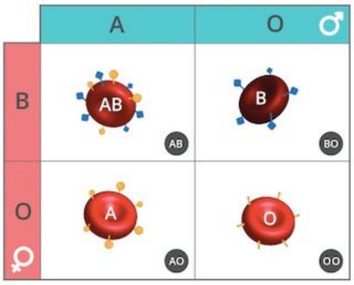


This screen will follow the previously mentioned condition of hemophilia and show the student how they can determine using pedigrees, whether a sample of blood was from someone with the condition and should not be used. This will orient the student to blood sample analysis and disease inheritance.

8) Punnett Squares and Blood Typing

Predicting Blood Types

Look at the results of the Punnett square. Label each potential child with the correct phenotype (blood type).



Genotype	Blood type
AA	Type A
BB	Type B
AO	Type A
BO	Type B
OO	Type 0
AB	Type AB

Use the Punnett square to determine which alleles(s) are dominant? (Dominant alleles suppress recessive alleles)

Here students will apply their knowledge of punnett squares to figuring out the possible blood types of offspring from a cross between and AO and a BO individual. This punnett square provides an example of codominance and prepares the student to find a matching donor sample for Jamal in the second mission.

9) Matching Jamal's Blood Type

Mission Part 2: Blood Types

In the last test, you eliminated one blood donor due to the risk that they may have had hemophilia. Now that you are more familiar with blood types, you'll want to check to see if the blood donations match Jamal's type B blood. One of the workers at the clinic has recorded the blood type of both parents for each of the three blood donors.

Select a sample to see if the blood donor matches Jamal's type B blood. Once you've checked all three samples, click *Next.*

10) Finding a Blood Match Without Sickle Cell

Mission Part 3: Sickle Cell Disease

You've narrowed down the blood samples to just two. You already know that neither of these two samples has hemophilia and both can be a match for Jamal's blood type. Now for the final test, you need to be sure that neither of the two remaining blood samples has any trace of sickle cell disease. This means the donors cannot be carriers of the disease or had the full disease itself.

Check the remaining two blood samples to see which one has no trace of the disease. Once you've checked both samples, click *Next*.

Sample #1
(From Malik)

Sample #3
(From Jojo)

11) Sickle Cell and the Risk of Inheritance for Jamal's Children

Their Child's Health

Predicting the chance that Jamal's child has sickle cell disease

Use a Punnett square to predict the chance that Jamal's newborn has sickle cell disease? (Jamal: SS Hana: AA)

Find out the chances of Jamal's child inheriting sickle cell disease by filling out the Punnett square below.

Jamal: SS

Hana: AA

	S	S
A		
A		

Here the student will predict the chance Jamal's child will inherit sickle cell disease by filling out a punnet square.

Rethinking Mendel

Take a moment to reflect on what you've learnt so far.

You learned in the previous lesson that Mendel proposed that when two different alleles or genetic factors were found in an individual, one always expresses dominance over the other.

Based on what you learned about sickle cell anemia, select all of the following that are true.

- [ ] Mendel was correct, a dominant allele always completely overshadows a recessive allele
- [ ] Mendel was incorrect, a recessive allele can overpower a dominant allele
- [ ] Mendel was correct a dominant allele cannot blend with a recessive allele
- [ ] Mendel was incorrect-a dominant trait can be expressed simultaneously with the recessive trait
- [ ] Mendel was incorrect-dominant and recessive alleles can sometimes blend to

Having completed the lesson, the student should understand that inheritance of traits and diseases is not always based off of the dominance of one allele over the other. Mendel only saw part of the picture but his initial experiments with pea plants are the foundation to other discoveries that followed.

Unit 3 Journey to the Galapagos: Peer Pressure in Nature

Lesson Stats
- Average time spent: 1-2 hours

Learning Objectives
- See Instructor's Guide

Assessment
Max Score: 167

Lesson Flow
- Introduction, Screens 2-5
- Food Chains: Autothrophs, Screens 6-14
- Food Webs, Screens 16-19
- Case Study: Rocky Mountains, Screens 20-33
- Introduction in Symbiosis, Screens 34-36
- Mutualism, Screens 37-39
- Commensalism, Screens 40-41
- Parasitism, Screens 42-43
- Analysis and Reflection, Screens 44-45
- Summary, Screen 46

Common Student Issues/Misconceptions
- Students should understand that although food chains are useful, they are a simplistic schematic for how energy is recycled in an ecosystem.
- Students may think that animals higher in a food web will eat what follows below them in a food web. However, just because an organism is higher doesn't necessarily mean that they eat all the organism lower on the food web.

Simulations
There is no simulation in this lesson.

Activity Walk-through

1) What are Food Chains? (Screen 6)

An Introduction to Food Chains

One of the most common interactions between organisms, and one that is a staple of almost any animal documentary, is the predator-prey relationship. These relationships fit into what is commonly referred to as a **food chain**. Contrary to what you may have learned in elementary school, a food chain is meant to show more than just who eats who. It's a diagram that shows how matter (nutrients) and energy (calories for example) are transferred from one organism to the next. Try reconstructing a food chain found in the Everglades region below.

Drag the organisms into the boxes below in the correct order to make this food chain. (from left to right)

2) Why are Autotrophs Important? (Screen 10)

Autotrophs

What's so important about these guys?

So what's so important about of these different autotrophs? What if we were to remove these autotrophs from the environment?

Which of the following answers best explains the effects of removing an autotroph in a food chain? Check all that apply.

- ☐ There would be no effect in the chain
- ☐ Organisms below the autotroph in the chain will gain more nutrients
- ☐ Animals high in the chain will be deprived

3) Different Types of Consumers (Screen 14)

Types of Consumers

Carnivores, Herbivores and Omnivores

Not all consumers are the same. Knowing what an organism consumes can help you determine how an organism fits into a food chain. There are three key types of consumers that populate most environments.

Carnivores- Organisms that primarily eat the meat or flesh of other animals.

Herbivores- that only feeds on plants or "herbs."

Omnivores --such as humans, that can eat *both* plants and other animals.

For the sake of learning, disregard any background knowledge you have about

4) Why are Food Webs Important? (Screen 17)

The Importance of Food Webs

How is information presented in a food web?

An alternative to using food chains is by visualizing an environment using a food web. A **food web** shows the interconnectedness of different organisms in an environment. Food webs can also help predict how organisms may be effected when another organism's population is being threatened.

What is true of the arrows used in a food web? Check all that apply.

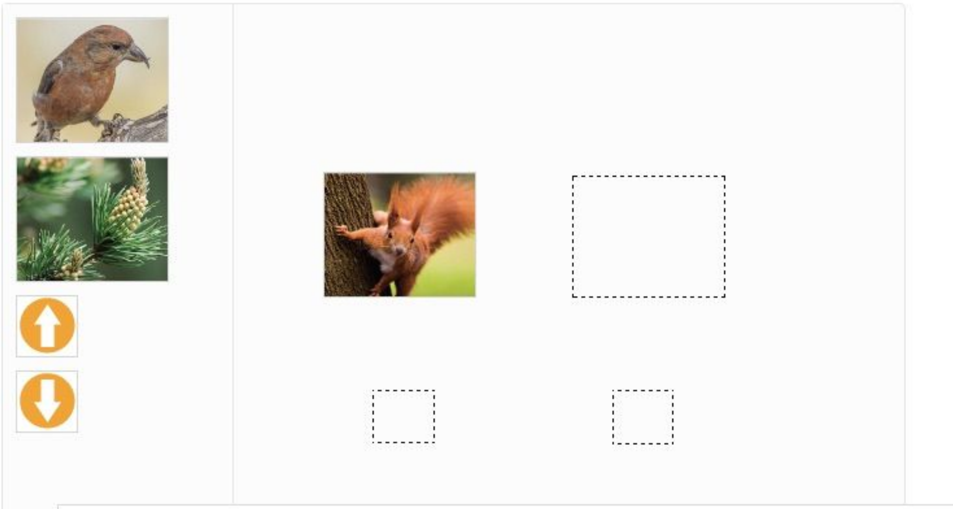
- [ ] The arrow head points towards the animal that is being consumed
- [ ] The arrowhead points towards the consumer

5) Design a Food Web

Create a Food Web

Rocky Mountains

Create a food web representative of the information you gathered about the organisms in the Rocky Mountains.

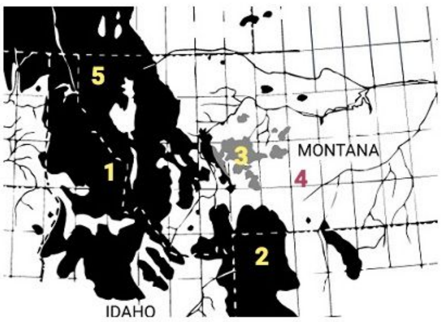


6) Conduct an Experiment

Choosing a Location

Which location would be most suitable for you to conduct this experiment?

It seems that the crossbills have difficulty getting past some of their prey's defenses--the pine tree's cones. In this case study you'll see if this difficulty in obtaining food will cause the predators--the crossbills--to change or develop new traits (over thousands of generations).Your aim will be to find out if the crossbill population will develop new traits or modifications to break the pine tree's defenses; or will the pine tree develop more defenses against the crossbill? Find a location below where you can test your hypothesis.



LEGEND

Black Areas = Areas with Squirrels, Pines and Crossbills

Grey Areas = Areas with only Crossbills and pines (no squirrels)

7) Experiment Ananlysis

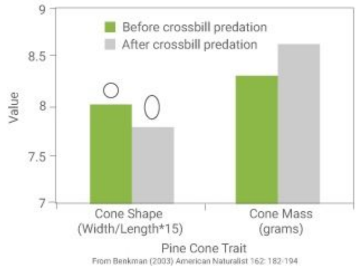
Effects of Crossbill Predation on Pines

Analyse the effects of the interaction between crossbills and pinecones

Now that you've found a location where crossbills can prey on Lodgepole pines without the interference of squirrels, you're now ready to see if a long-term interaction between these two species can cause a change in the traits of their populations. This can occur in two ways:

- The crossbills can cause trait changes in the pine population (such as developing thicker cones) or
- The pine trees can cause trait changes to emerge in the birds (such as developing thicker beaks).

Let's start by focusing on whether the pressure of crossbill predation causes the



8) Types of Symbiotic Relationships (Screen 35)

Symbiotic Relationships

What role does each partner play in a symbiotic relationship?

Although symbiotic relationships may not appear on a food web, they are key to answering our overarching question for this lesson: "how are there so many different traits in the world around us?". To survive, some organisms may adapt or change their behavior or physical traits to be able to better use others around them.

There are many different types of symbiosis. One example of symbiosis is the relationship between the mongoose and the hornbill that you've seen earlier. Another example of the same type of symbiotic relationship occurs between the clownfish and the sea anemone.

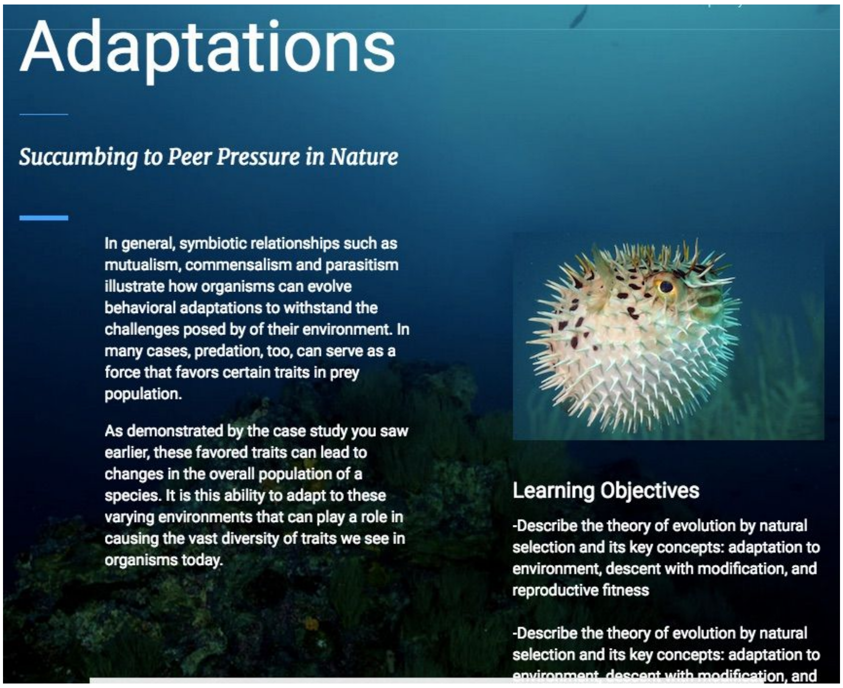
Sea anemone, though seemingly harmless, are predators that attack nearby fish with their tentacles. However, they provide a home for clownfish who have developed a thick layer of mucus against the anemone's stings. In return , the clownfish lures prey towards the anemone.

To understand this symbiotic relationship, record what happens to each of the organisms involved.

Clownfish

Sea Anemone

9) Summary (Screen 46)


Adaptations
Succumbing to Peer Pressure in Nature
In general, symbiotic relationships such as mutualism, commensalism and parasitism illustrate how organisms can evolve behavioral adaptations to withstand the challenges posed by of their environment. In many cases, predation, too, can serve as a force that favors certain traits in prey population.
As demonstrated by the case study you saw earlier, these favored traits can lead to changes in the overall population of a species. It is this ability to adapt to these varying environments that can play a role in causing the vast diversity of traits we see in organisms today.
Learning Objectives
-Describe the theory of evolution by natural selection and its key concepts: adaptation to environment, descent with modification, and reproductive fitness
-Describe the theory of evolution by natural selection and its key concepts: adaptation to
environment, descent with modification, and

Unit 3 Journey to the Galapagos: The Birds and The Moths

Lesson Stats
- Average time spent: 1.5 - 2.5 hours

Learning Objectives
- See Instructor's Guide

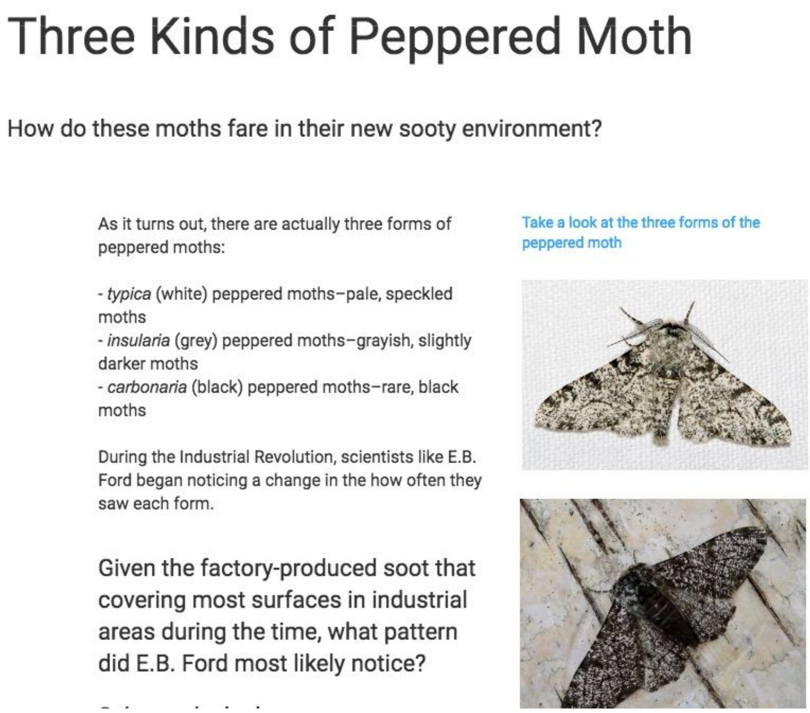
Assessment
Max score: 202

Lesson Flow
- Introduction for the Peppered Moth, Screens 1-4
- The Industrial Revolution and Environmental Change, Screens 5-7
- Moths Before the Industrial Revolution Simulation and Analysis, Screens 10-15
- Moths During the Industrial Revolution Simulation and Analysis, Screens 16-24
- Evidence of Change after Pollution, Screens 25-29
- Reducing Pollution and Resulting Population Change, Screens 30-31
- Questioning the Kettlewell Study, Screens 32-34
- Population Growth Rates of Rabbits, Screen 35-41
- Factors Limiting Population Growth, Screens 42-44
- Selective Pressure and Adaptation, Screens 46-47
- Reflection and Summary, Screens 48-49

Common Student Issues/Misconceptions
- Students should come to understand that individuals do not develop traits in response to their needs. Rather, those traits, such as moth wing color, develop across generations in response to environmental pressures (pollutions and predation).

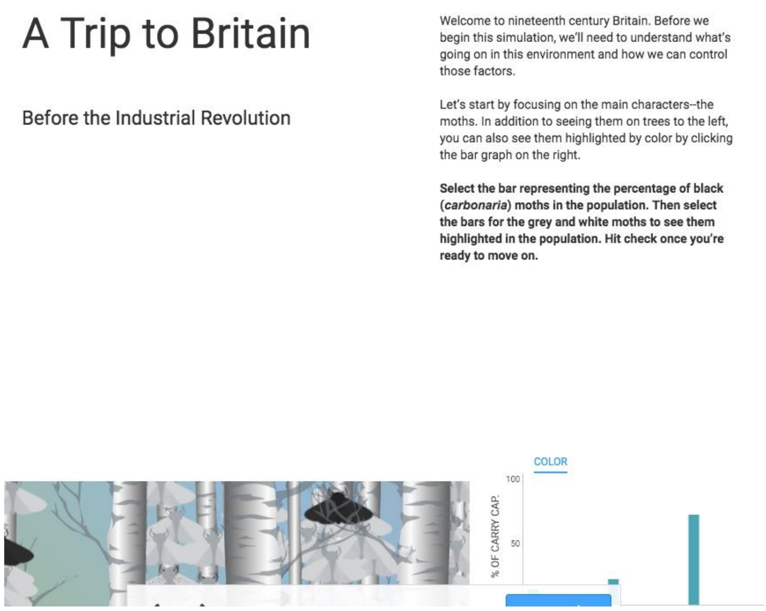
Simulations
Simulation name: Moth Population
- Description: This simulation allows students to adjust the level of environmental pollution by regulating the number of factories, predators, and other factors.
- Correct answer: Student's must increase the number of factories present in the environment in order to indirectly increase the population of the darker winged moth varieties. Likewise, the students must increase the predation rate so that there is a selective pressure for the dark colored moths in an ever more polluted and thus darker habitat. If the students set the predation rate to be too low then there will be no selective advantage for the darker wing moths.

Activity Walk-through
1. Introduction to the Peppered Moth



Here students will become familiar with the pepper moth and more generally how species adapt to changes in the environment such as air pollution.

2. Simulating the Peppered Moth Populations Before the Industrial Revolution



Here is the first time in the lesson that students will use the simulation to visualize which moth wing colors were present without the industrial revolution pollution serving pressure.

3. Simulating the Peppered Moth Populations During the Industrial Revolution

Recreating the Industrial Revolution

The SIM is currently set to Pre-Industrial revolution settings. You may notice that there is not too much soot in the forest on the left.

Now let's try to recreate Britain's industrial revolution.

See what effect changing the number of factories in the city nearby has on the environment.

To do this, maximize the number of factories and then press the play button on the timeline below. See how this affects the environment over time
Once you're ready to move on, hit check.

Here is the first time in the lesson that students will use the simulation to recreate the effect of industrial pollution on pepper moth coloring.

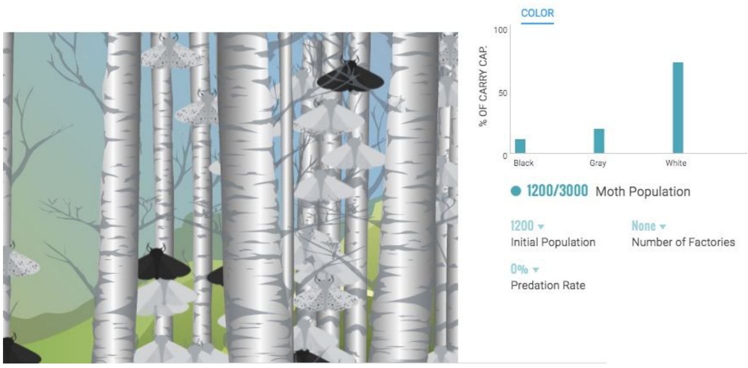
4. Controlling for Factors in the Moth Simulation

Discover two additional factors you can control in the moth population

Props for the can-do attitude. This information will be helpful later on.

Alright, what do you want to know more about?

- A. Adding predators to my environment
- B. Adding more moths to my environment



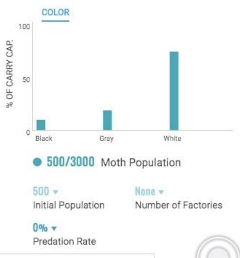
Predation Rate

Bumping up the number of predatory birds

One factor you can control in the environment is the predation rate. The **predation rate** represents the percent of moths killed by predators (in this case robins).

See what effect changing the predation rate has on the types of moths in the environment.

Once you're ready to move on, set the predation rate to 25%, play the simulation, and then hit check.



Here students can experiment by adding other selective pressures to the environment such as predatory birds. It is recommended that students choose a high predation rate, then press the play button on the timeline below.

5. Calculating Peppered Moth Populations After Industrial Revolution

Evidence of Change

How did Kettlewell know that moths of one color were becoming more popular than others?

After the Industrial Revolution, Kettlewell marked, released and captured moths in a wooded area in an industrial region of England each day over a two week period in 1953 to study the survival of the different phenotypes in the wild in the face of natural predators.

Kettlewell's data is summarized below.

Data from Kettlewell's experiment

	carbonaria	*typica*	*insularia*
Number released	447	137	46
Number caught	651	81	38
Number caught that were released	123	18	8

Use the data to answer the questions to the right. **Enter only a number, without units or percentage signs.**

To calculate a percentage, divide the number of one part of the sample by the total amount in the sample, then multiply by 100.

For example, if 5 moths in a sample of 47 were *typica* (white), the percentage of typica would be:

$\frac{5}{47} \times 100 = 10.6\%$

For the number released:

How many total moths were released?

How many *carbonaria* forms were released?

What percentage of the moths were *carbonaria*?

In this activity students will read the table and calculate the percentage of different moth colors in a population of moths, in an attempt to follow what Kettlewell did.

Unit 3 Journey to the Galapagos: Galapagos Exploration

Lesson Stats
- Average time spent: 2-3 hours

Learning Objectives
- See Instructor's Guide

Assessment
Max score: 360

Lesson Flow
- Introduction and Galapagos Information, Screens 1-4
- Observing Species on Hood Island, Screens 5-6
- Observing Species on Isabela Island, Screens 7-6
- Observing Species on San Cristobal Island, Screens 9-10
- How to Gather Evidence on the Galapagos, Screens 11-12
- Determining a New Species by their Differences, Screens 13-16
- Simulation: Create a New Species in 40 Generations, Screens 17-18
- Simulation and Analysis: Daphne Major Challenge, Screens 20-27
- Modes of Selection and Beak Depth, Screen 28
- Directional Selection, Screens 29-33
- Natural Selection, Screens 34-36
- Simulation: Determining a New Species, Screens 37
- Species and Speciation, Screens 38-39, 41
- Review Speciation and Natural Selection, Screens, 42-44
- Sexual Selection, Screen 45
- Artificial Selection, Screen 46
- Selective Pressure Review Table, Review 47
- Simulation Challenge #2: Natural and Sexual Selection Pressures, Screens 48-50
- Simulation Challenge #3: Importance of Initial Population on Floreana Island, Screens 51-54
- Simulation Challenge #4: Predation and Hood Island, Screens 55-58
- Simulation Challenge #5: A Single Species on Santa Cruz, Screens 59-61
- Simulation Challenge #6: Speciation I on San Cristobal, Screens 52-70
- Simulation Challenge #7: Potential Speciation on Isabela Islands, Screens
- Types of Speciation, Screens 72-76
- What is Evolution, Screens 77-80
- Summary and Reflection, Screen 81

Common Student Issues/Misconceptions
- Individual organisms do not evolve but populations of organisms do. All the activities in this lesson emphasis this point.

- Once misconception about natural selection is that is it a process striving to produce organisms of greater complexity. Natural selection — and evolution more broadly — is better thought to be a mechanistic process where variation, heredity, and differential reproduction help facilitate what might appear to be a guided process.

Simulations

Simulation name: Challenge 1: Rainfall on Daphne Major Part 1 and Part 2

- Description: In this simulation students are to create a population of finches where 80% have large beaks over the course of 100 generations. Students can only control levels of rainfall.
- Correct answer: In order to get a higher percentage of large beaked birds students should limit the amount of rainfall on the island.

Simulation name: Challenge 2: Multiple Pressures on Fernandina

- Description: Now that students have a better understanding of how selective pressures such as natural, sexual, and artificial selection can affect the traits in a population, they are to adjust these parameters to see how they can create a population where 80% of the finch population has large bodies over 30 generations.
- Correct answer: Students should make sure to adjust level of rainfall to “light” and the mate preference to “selective”. Female finches tend to prefer males with larger bodies. By increasing their mating preference, they are more inclined to mate with large-bodied males. This allows the large-body trait to be passed onto future generations.

Simulation name: Challenge 3: Initial Population on the Island of Floreana

- Description: On the Island of Floreana, most of the finches in the population have large beaks. Students are to adjust the initial population parameters and selective pressures such as rainfall and mate preference to shift the population so that 80% of the birds have small beaks in 80 generations.
- Correct answer: Students will be able to create a next species in 80 generations if they set their parameters in the following ways: initial population (around 600-980), heavy rainfall and random mate preference.

Simulation name: Challenge 4: The Effects of Predation Rate on Hood Island

- Description: Here students experiment with what it must to make an entire population of finches on Hood Island go extinct.
- Correct answer: In order to make an entire finch population go extinct students can adjust the hawk predation level to 100%.

Simulation name: Challenge 5: A Single Species on Santa Cruz

- Description: Students are to try to keep the population of finches on the island of Santa Cruz a single species for 60 generations.
- Correct answer: Students can prevent a new species from emerging by keeping rainfall and mate preference at a middle point.

Simulation name: Challenge 6: Speciation on San Cristobal

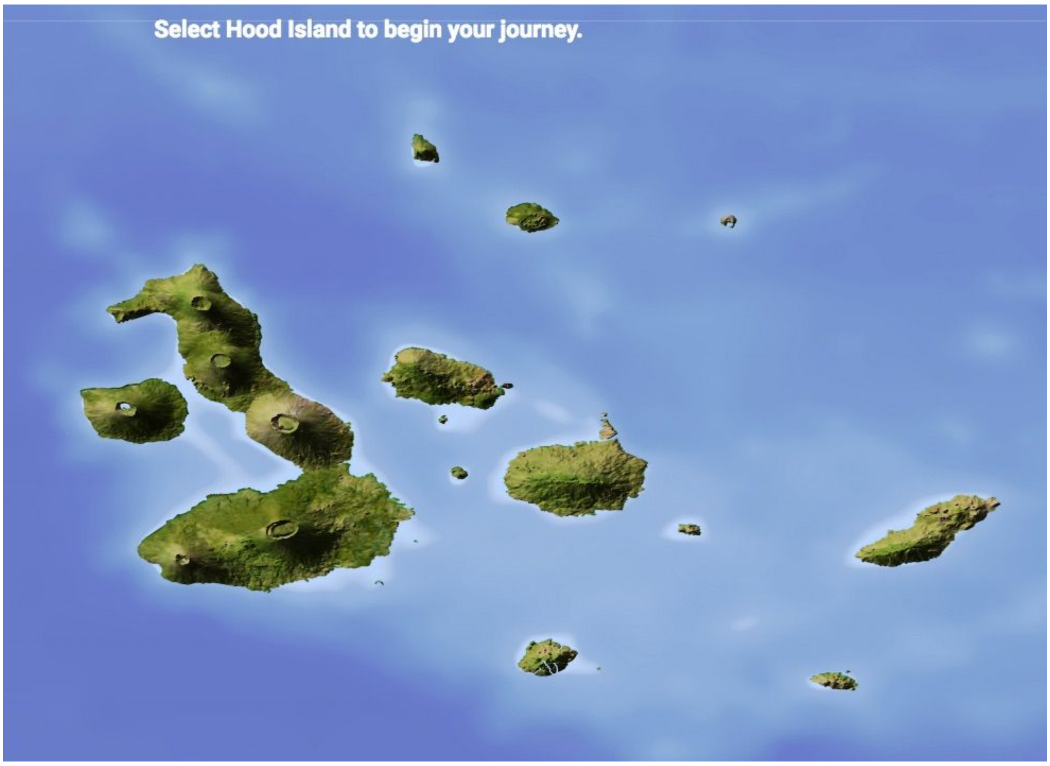
- Description: Students are to use the number of cacti and insects on this Island to create two species of finch. Shift the traits in the population in two directions so that there are finches with large and small bodies but very few with mid sized bodies.
- Correct answer: Two extremes in beak size are favored by increasing the amount of insects and cacti on the island. After many generations, birds without either extreme trait are not as common.

Simulation name: Challenge 7: Speciation on Isabela

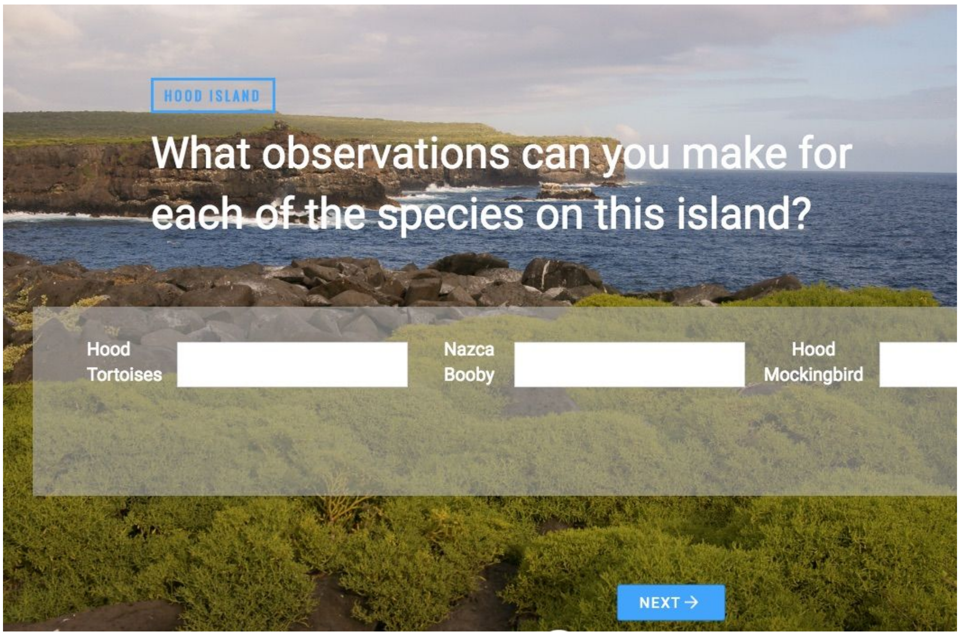
- Description: Using the resources on both sides of the island and other variables, students are to create two new species of finches from the original population.
- Correct answer: To become two different species, both groups on either side of the island have to develop different traits. While they both started out with average-sized beaks, one group developed large beaks while the other developed small beaks.

Activity Walk-through

1. Observing Species on Hood Island

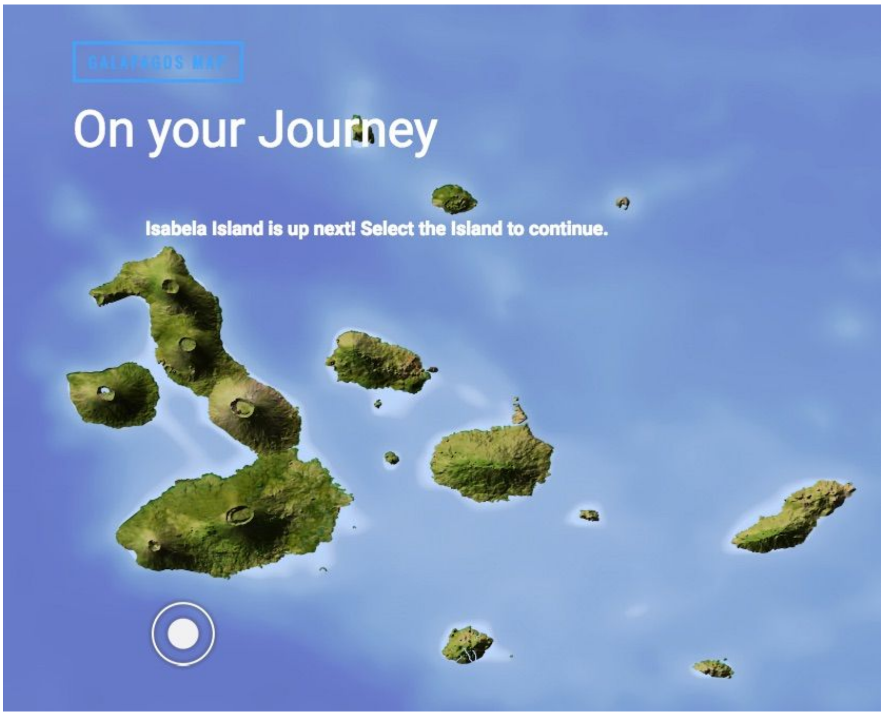


This is the first observational activity that students will encounter in this lesson. Students will examine various species across the islands of the Galapagos. It is important that students pay close attention to what makes each listed species different from each other and how those differences could have emerged.

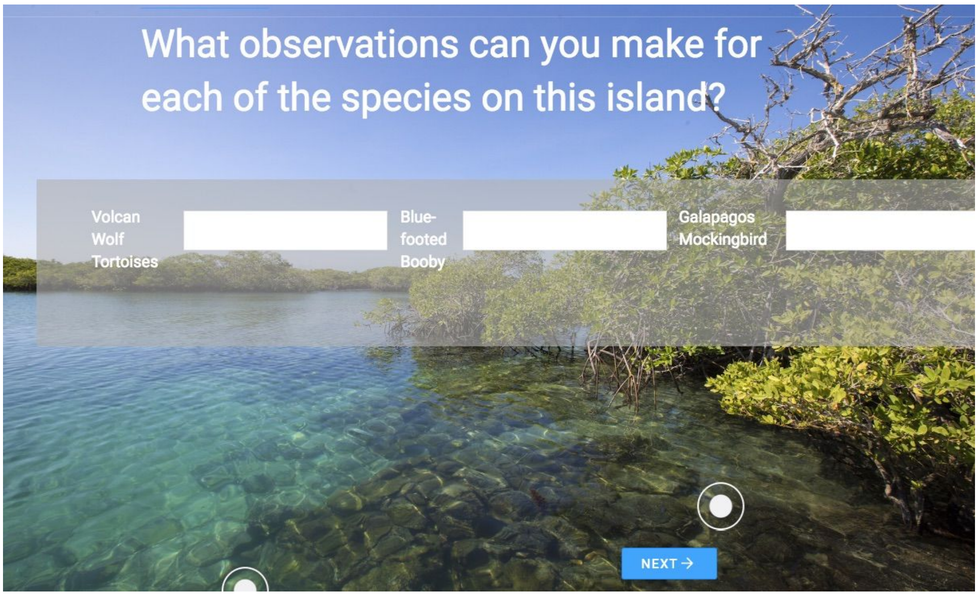


After clicking a white circle on a specific island (In this screen it's the Hood Island) on the map of islands, the students are brought to a page where they are to observe three species. Each species is marked by a white circle (not visible in this screenshot). Once students click the circle they are provided with a pop-up window of the species that includes a description and pictures. The student is to use that information to fill in the white rectangular text box next to the animal's name. If the student is having difficulty locating the white circles, they are advise to drag around the screen until they locate them. Once each text box is filled the student should hit the "Next" button to be taken to Isabela Island.

2. Observing Species on Isabela Island

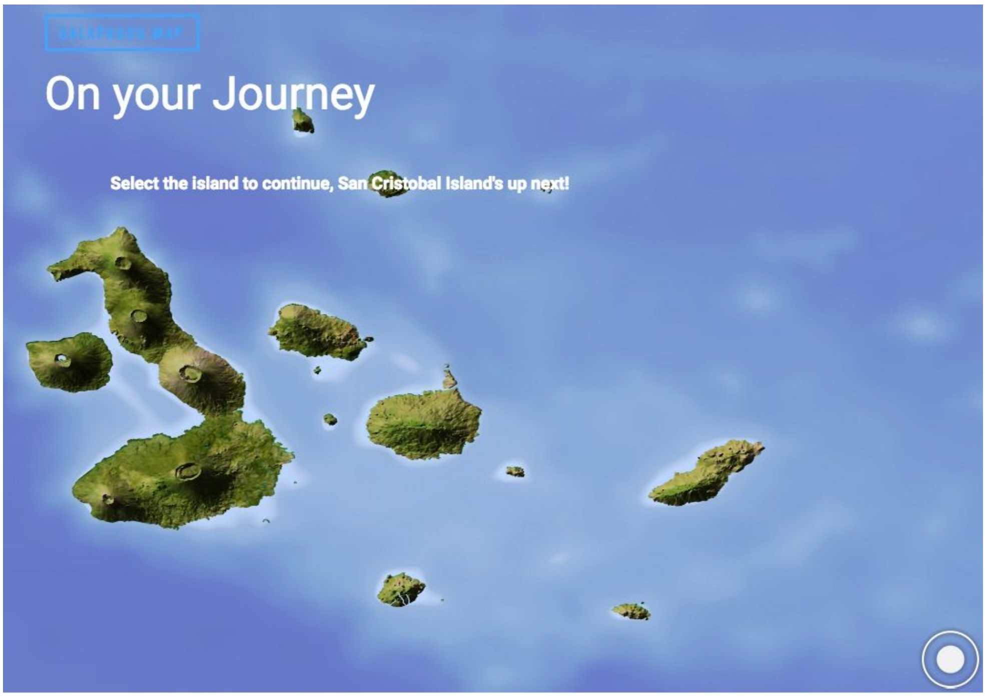


This is the second observational activity students will encounter in this lesson. The same directions apply to each island the student focuses on. Here the white circle denoting Isabela Island can be seen. The same as in Hood Island, the student must click on the circle to be taken to the ecosystem where the species they are to identify live.

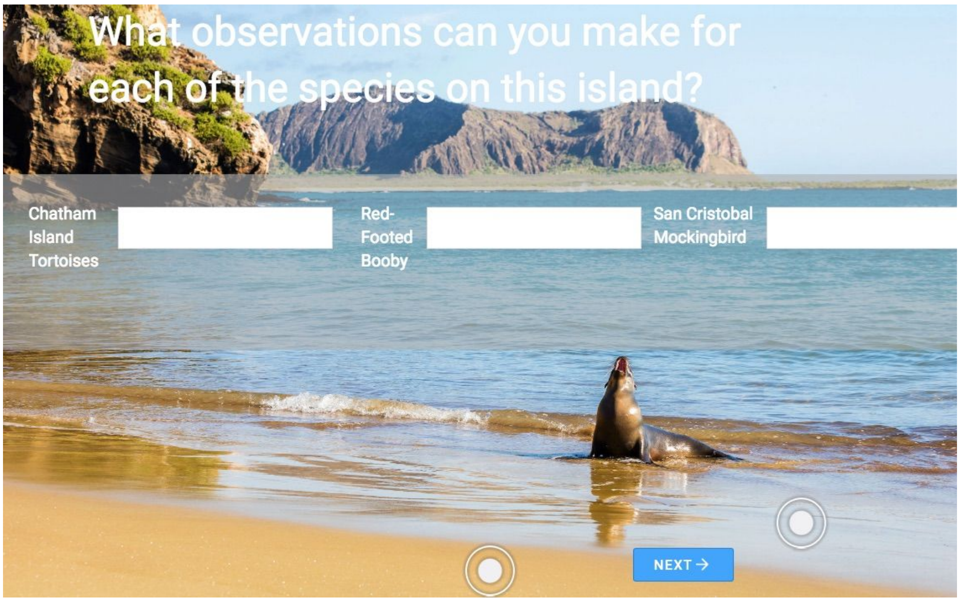


After clicking the white circle students are taken to this page where they can click on more white circles to collect information about the specific species that live on Isabela Island. Students will enter their observations into the rectangular text box next to the species name.

3. Observing Species on San Cristobal Island

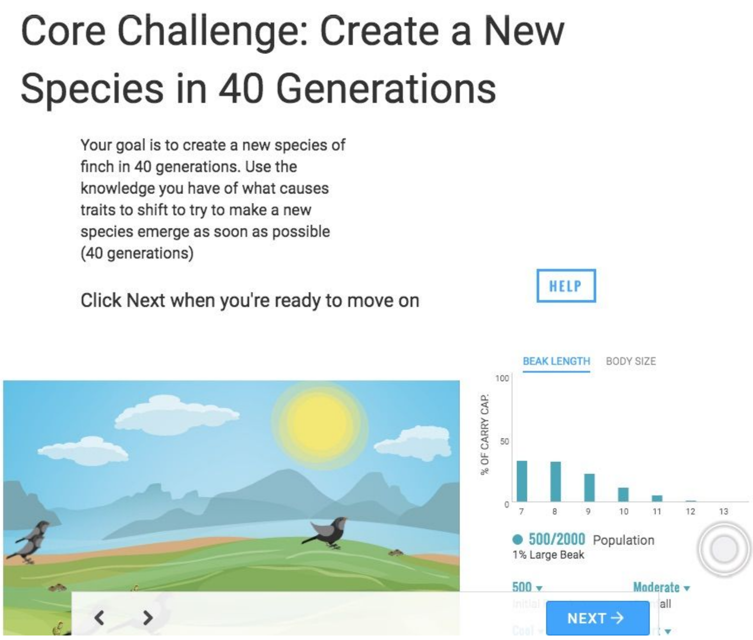


Just like with the Hood and Isabela Island activity, students will click the white circle to be taken to the San Cristobal island ecosystem.

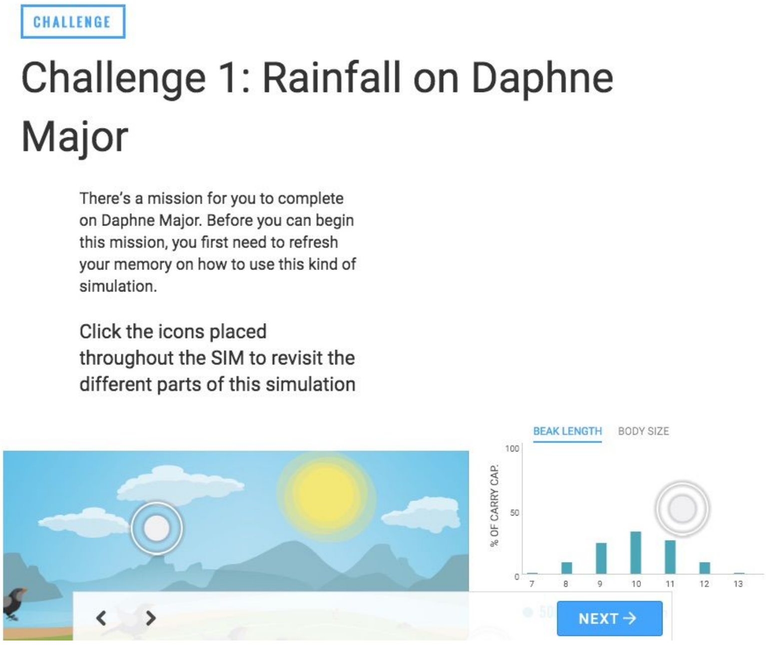


Students will continue to click on the white circles to find out information about the animals living on San Cristobal.

4. Creating New Species

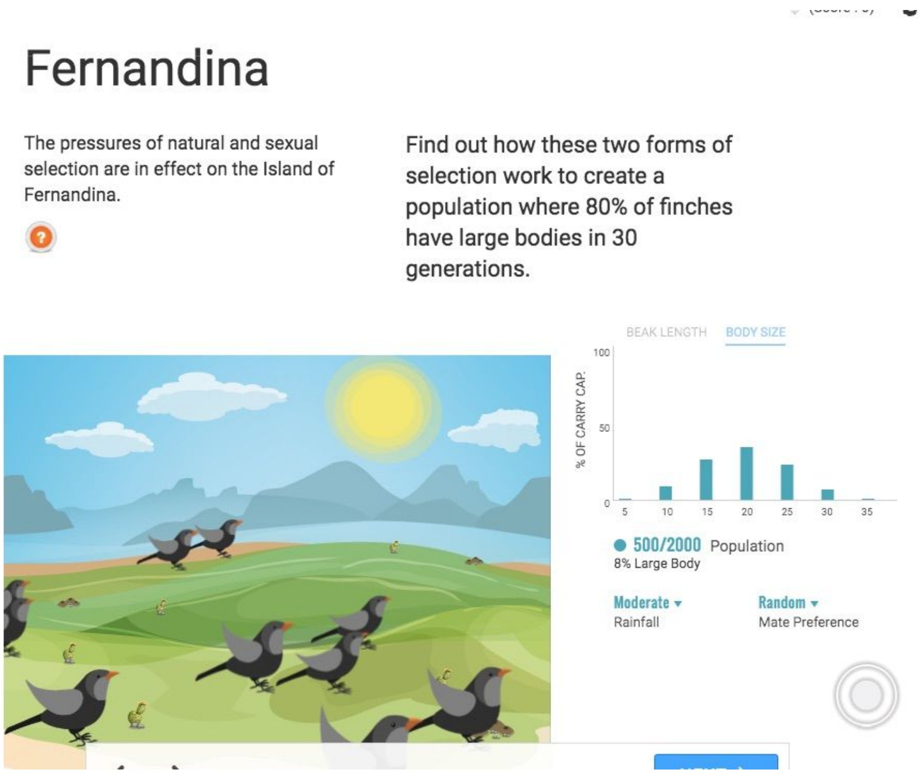


On this screen students will use a simulation to see whether they can create a new species of finches in forty generations by adjusting for rainfall levels. This will prepare students to consider factors such as initial population and environmental factors on speciation. The importance of these factors will be discussed in greater depth later on in this activity.



Here students will use a simulation to study the pressure of natural selection on a population of finches over time. Specifically, students will look at the effect of rainfall on different species and pay attention to characteristics such as beak length and body size. This activity is meant to introduce the concept of natural selection.

5. Natural and Sexual Selection on the Island of Fernandia



In this simulation students will look at natural and sexual selection acting on a population finches. The natural pressure will be the amount of rainfall while the sexual pressure is denoted by mate preference.

6. Does a change in Beak Size Make a /new Species

Are the Large-Beaked Birds a New Species?

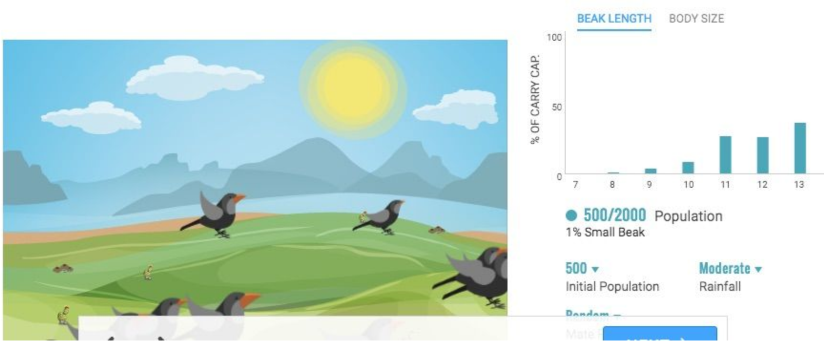
A change in the rainfall (and therefore seeds available) can be an example of natural selection because it puts a pressure on the finch population. Finches with larger beaks are more fit to survive and reproduce. But can having a larger beak make the finches with that trait a new species?

Take a look at your simulation. Play the timeline to see if the birds with the small beak and large beak traits have become two different species after 100 generations.

7. How Does the Initial Population of Finches Impact Speciation

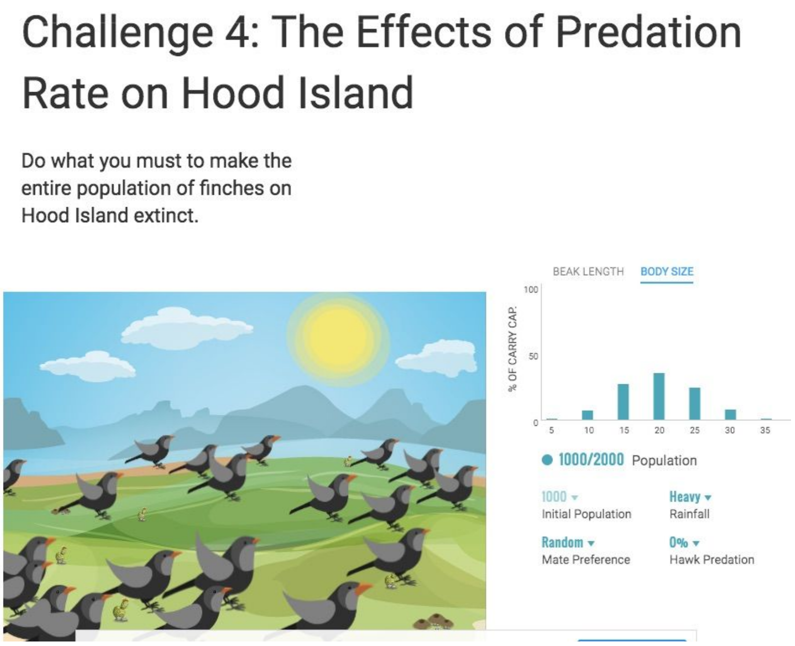
Challenge 3: Initial Population on the Island of Floreana

On the Island of Floreana, most of the finches in the population have large beaks. Adjusting the initial population parameter and selective pressures, shift the population so that 80% of the birds have small beaks in 80 generations.



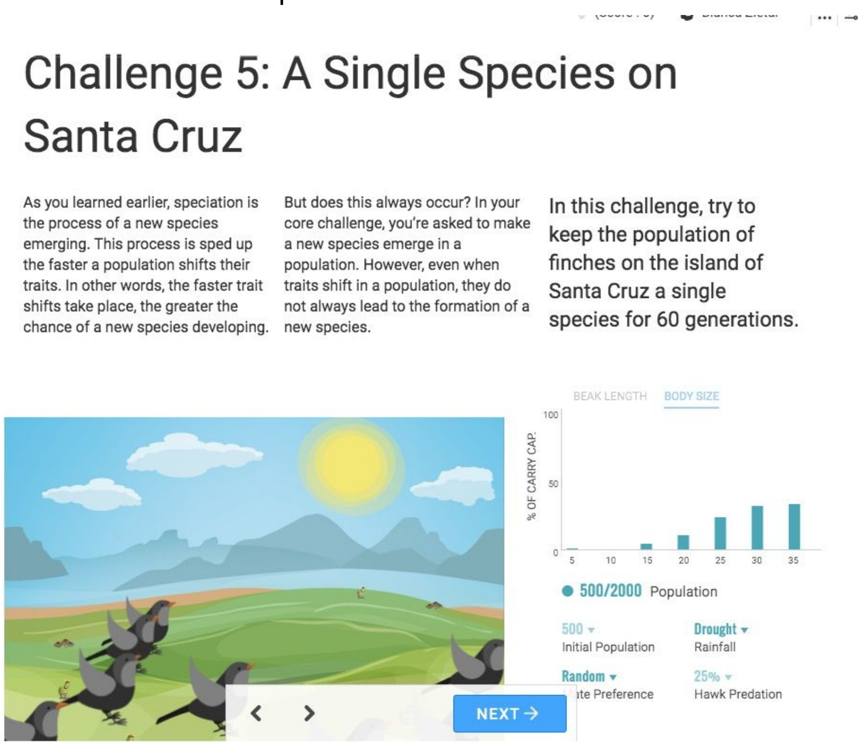
In this activity students can adjust a number of variables in order to facilitate the speciation of finch species. There are several combinations of adjustments that will result in a new species emerging and the student should feel free to experiment.

8. How Does Predation Impact Finches on Hood Island?



Here students will see how increasing the amount of predators will affect the population of finches.Too much predation and the finches will go "extinct", too little and there might not be enough selective pressure to cause speciation.

9. How to Prevent Speciation



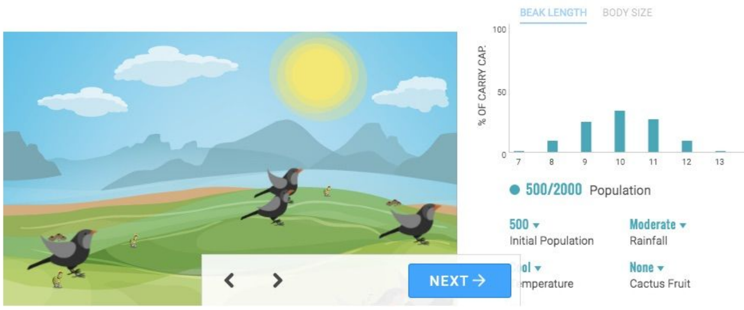
In this activity students get to manipulate several variables representing environmental pressures affecting a population of finches and are challenged with the task of keeping the population as a single species. This is more easily achieved if the pressures are kept to a minimum.

10. Create a New Species Through Dietary Choices

Challenge 6: Speciation on San Cristobal

Use the number of cacti and insects on this Island to create two species of finch. Shift the traits in the population in two directions.

To complete this challenge, you'll have two new variables. Check to see how each one works individually before using both at the same time.



In this activity students are to adjust the abundance of different food sources (insects and cacti) to see what effect this has on the finch population. The goal for students is to see if they can create a now species by adjusting the prevalence of insects and or cactus fruit.

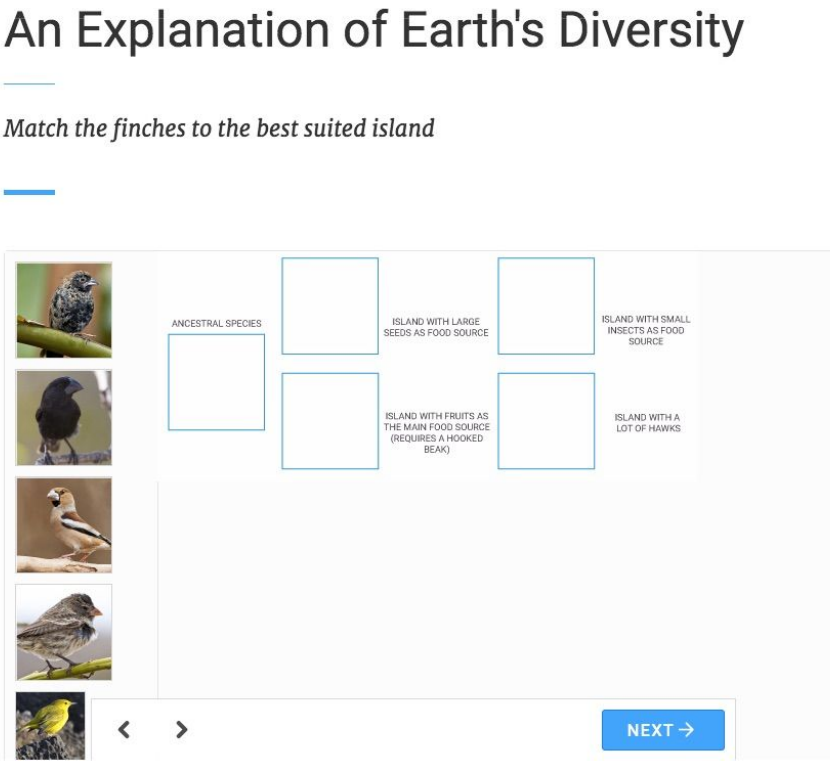
11. What is the Effect of Geological Boundaries on a Species

Challenge 7: Speciation on Isabela

Using the resources on both sides of the island and other variables, create two new species of finches from the original population.

Is it possible for a mountain range that divides a finch population to create a new species? Find out.

12. Finch Activity



In this activity students must apply what they learned about finch evolution and match up the pictures of finches with a description of the environment they would likely be from given their beak shape and body size.

Unit 4 Time Traveller’s Guide to Life on Earth — Written in Stone

Lesson Stats
- Average time spent: 0.5-1 hour

Learning Objectives
- See Instructor's Guide

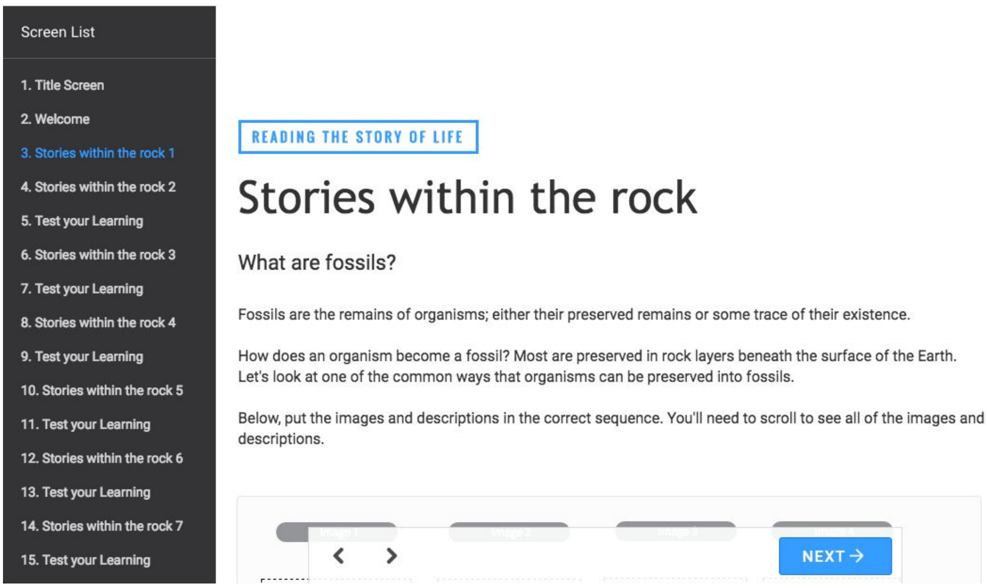
Assessment
Max score: 139

Lesson Flow
- Welcome, Screen 2
- Stories within the rock, Screens 3-16
- Stacking Example, Screens 18-19
- Construct a rock column, Screens 20, 26
- Visualizing deep time, Screen 27
- Time Traveling, Screen 29
- 560mya, Screen 30
- 65mya, Screen 31

Common Student Issues/Misconceptions
- Students often struggle with the concept of deep time and the varied methods for dating rock and fossils.

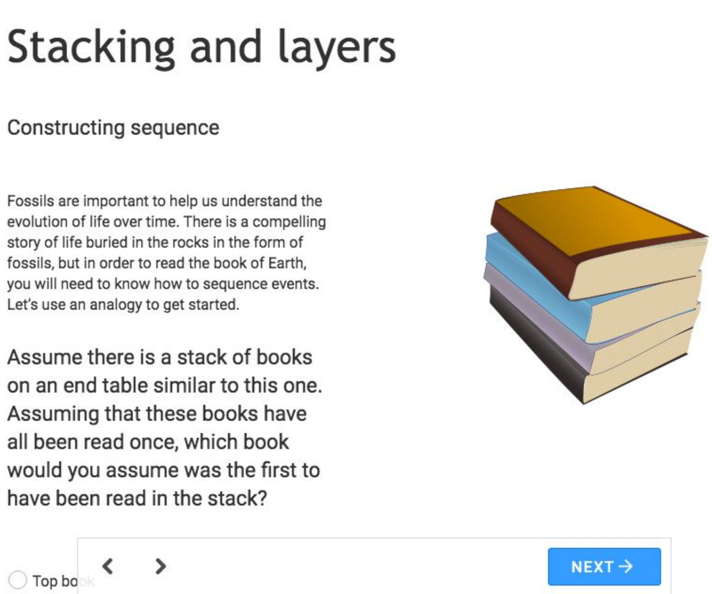
Activity Walk-through

1. Stories within the rock, Screen 3



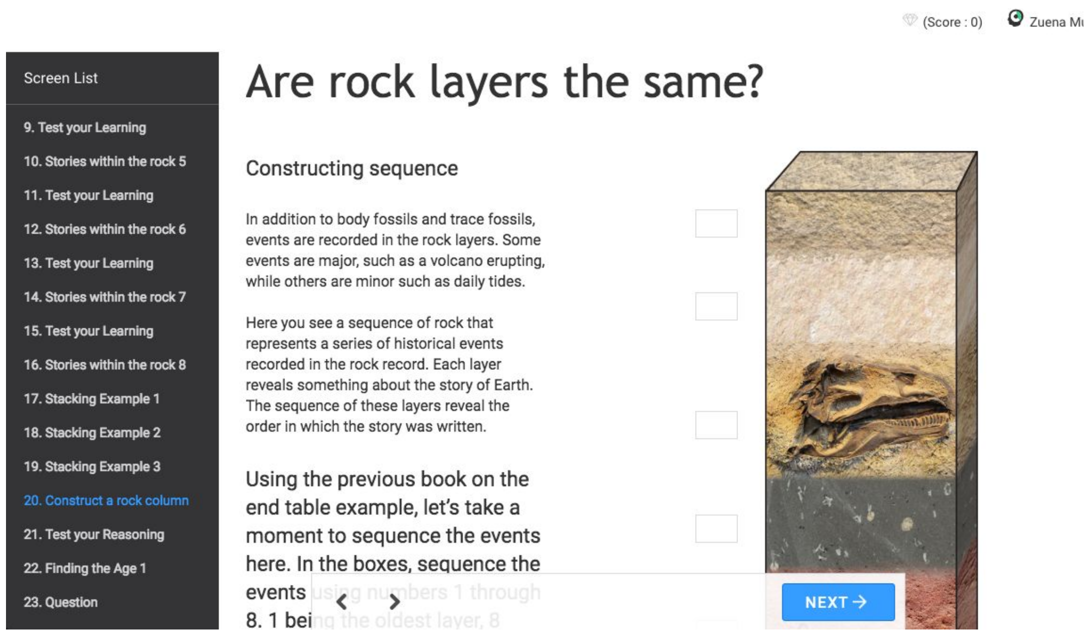
Students are asked to put images and descriptions in order to determine how organisms can be preserved into fossils. This slide helps students the basic fossilization process.

2. Stacking Example 1, Screen 17



Students are shown how to construct sequences through using an example of stacking books.

3. Construct a rock column, Screen 20



Using the stacking example, students are asked to sequence events to reveal the order in which historical events were recorded in the rock record. Students will have to use information from previous slides.

Unit 4 Time Traveller's Guide to Life on Earth — End of an Era: Hell Creek, USA

Lesson Stats

- Average time spent: 1-2 hours

Learning Objectives

- See Instructor's Guide

Assessment

Max score: 154

Lesson Flow

- Welcome, Screen 2
- How to Move/Instructions, Screens 3-4
- Intro Video, Screen 5
- Your Prediction, Screen 6
- Evolution of Terminology, Screen 7
- Old/New Naming of the Boundary, Screens 8-9
- Hall Creek, Screens 13-19
- What Lived in Hell Creek, Screens 20-23
- Tullock Formation, Screens 24-36
- Hell Creek vs Tullock Video, Screen 38
- Conclusion, Screen 41

Common Student Issues/Misconceptions

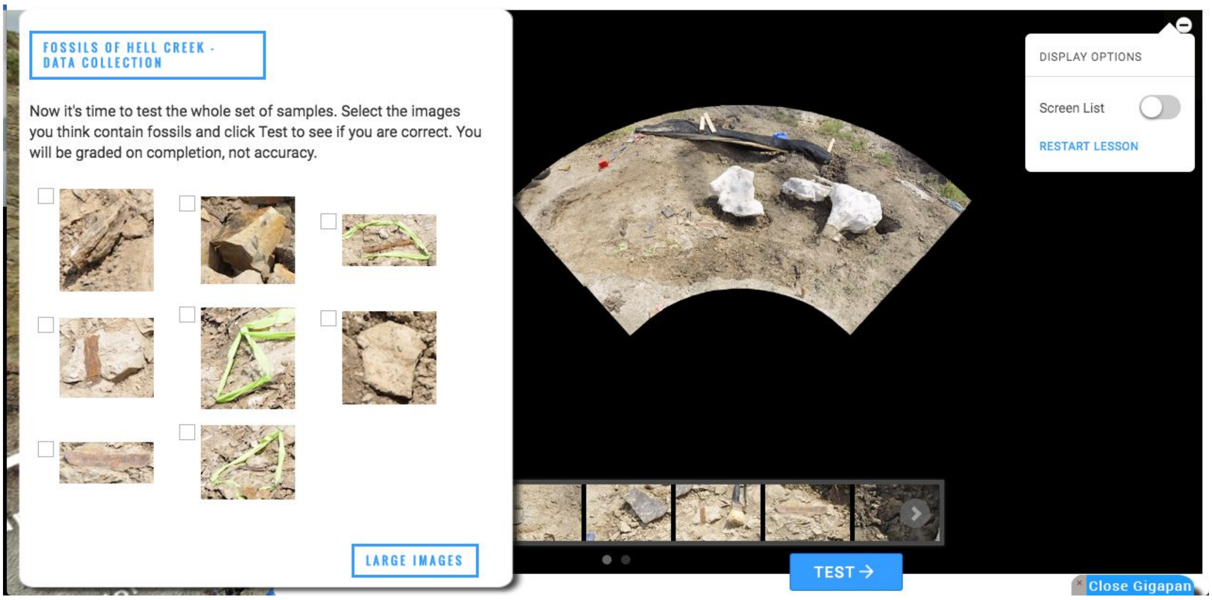
- N/A

Activity Walk-through

1. How to Move, Screen 3

Students are taught how to navigate through this lesson by exploring the location. This slide is important as it helps students understand how to explore the slides, which is different from the lessons in the previous units. If students are having trouble with navigation, refer them to this slide.

2. Hell Creek - Data Collection, Screen 14



Students are asked to watch multiple videos and navigate through Hell Creek and then determine which of these samples contain fossils. The slides after this ask the student to determine whether each of the bone fossils are either a body fossil or a trace fossil. Students might have trouble with determining which of these samples contain fossils, if so, ask them to rewatch the videos in the previous slide.

Unit 4 Time Traveler's Guide to Life on Earth — Rise of the Animals: Nilpena Ecosystem

Lesson Stats

- Average time spent: 1.5-2.5 hours

Learning Objectives

- See Instructor's Guide

Assessment

Max score: 139

Lesson Flow

- Introduction, Screens 1-2.
- The Environment, Screens 3-13.
- Deep time, Screens 14-26.
- The Rocks, Screens 27-44.
- Fossil Identification and Identification Key, Screens 45-109.
- Build an Ecosystem, Screens 110- 406.
- Review and Summary, Screens 407- 412.

Common Student Issues/Misconceptions

- Students may struggle with the Deep Time drag-and-drop activity because they not only need to take the order of the events into consideration but also the events proximity to one another. It is crucial that students drop in an event icon into the correct dotted box.
- Students may also run into issues locating the various arrows and magnifying glasses that are present during the fossil identification portions of this lesson. It is crucial for students know how to maneuver in the 360 panoramic view of the Flinders Ranges so that they can later find them as they appear in the lesson.

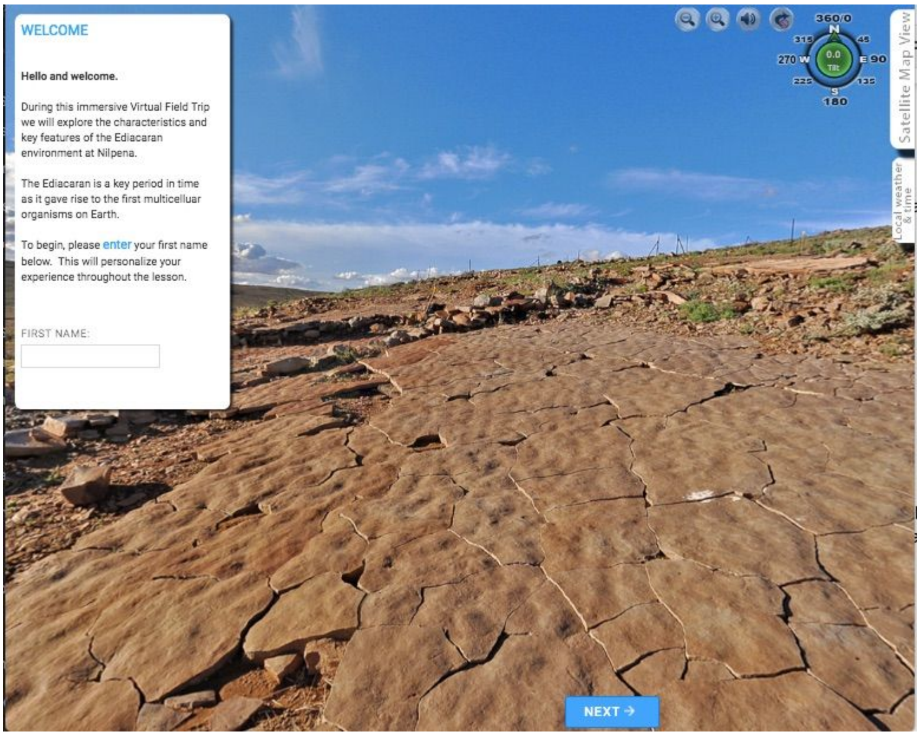
Simulations

Simulation name: Build an Ecosystem

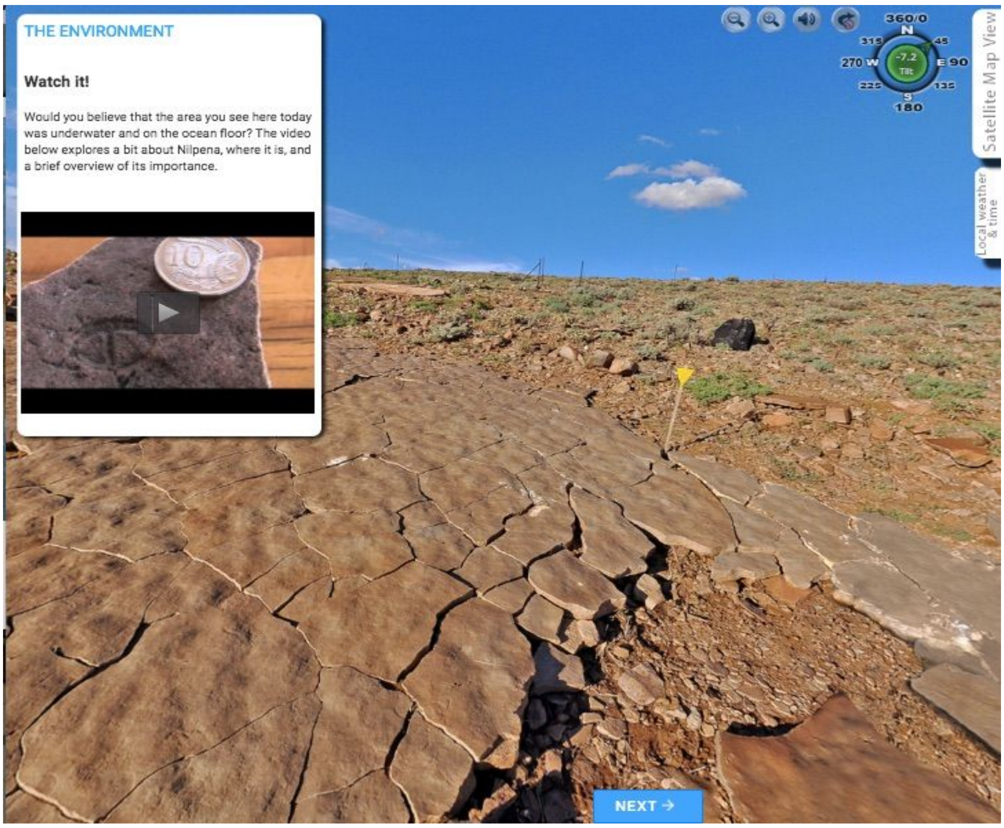
- Description: This simulation displays an undersea ecosystem that students can manipulate the conditions of in several ways. The possible conditions include water depth (shallow or deep), water type (tropical marine or freshwater), surface conditions (waves with some storms or very still and calm water), and seafloor type (rocky, sandy, or muddy). If students do not select the correct conditions in their first try they can select “redo” until they achieve an environment that is most like that of the Ediacaran.
- Correct answer: Students are correct when they select the conditions that are most like that of the ediacaran period.

Activity Walk-through

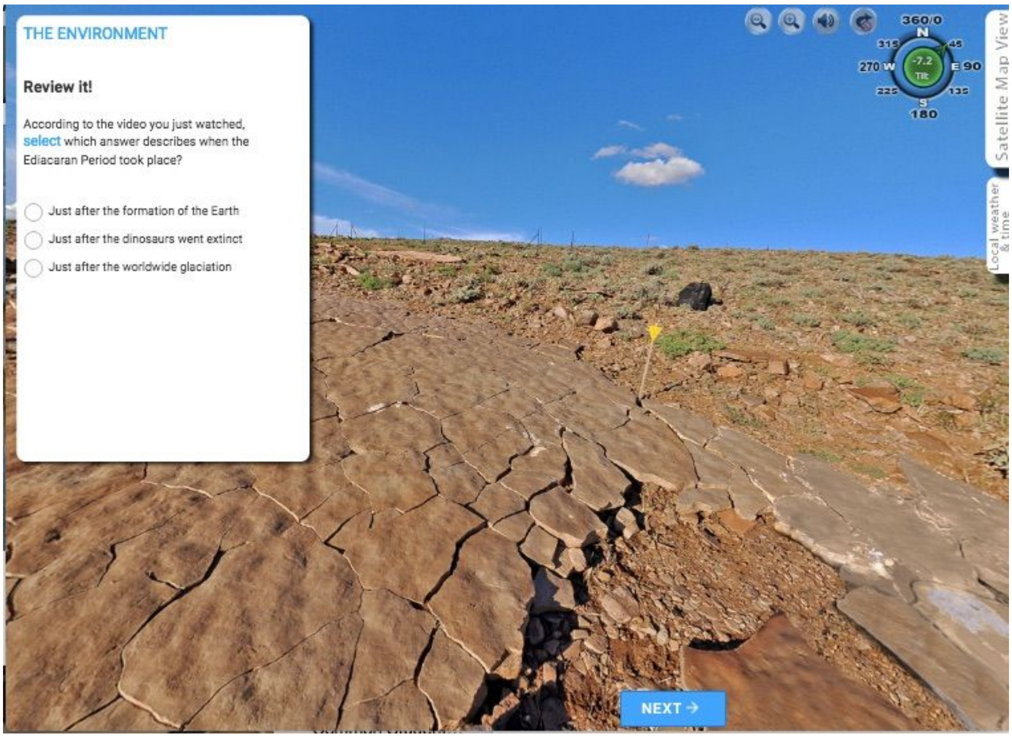
1. Introduction to the Nilpena Environment



On this screen students will see for the first time the environment they will study throughout the entire lesson. The first following slides introduce students to the Nilpena field site located in the Flinders Ranges of South Australia. Students can click and drag on the screen for a panoramic view of the landscape they are studying. Throughout their exploration students are provided with informational videos critical to answering later video content questions.

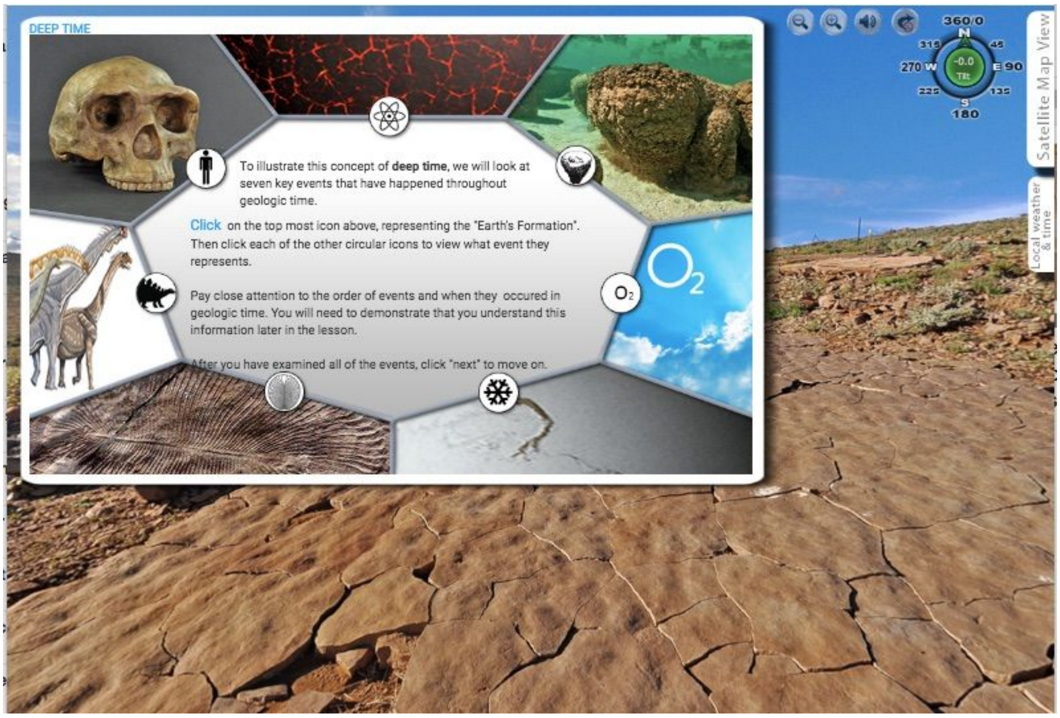


This screen is the first of several screens that include an informational video about the Nilpena ecosystem and the many fossils found in the beds found there.



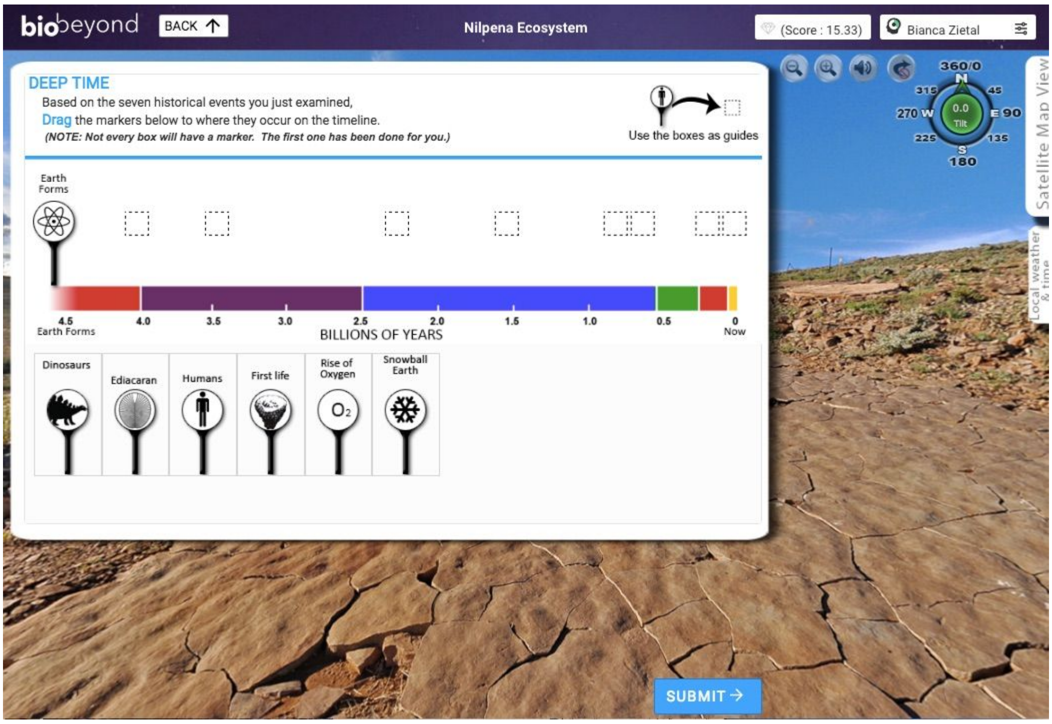
After watching the informational video students must answer questions related to the content of the video.

2. Deep Time Intro (Screen 16)



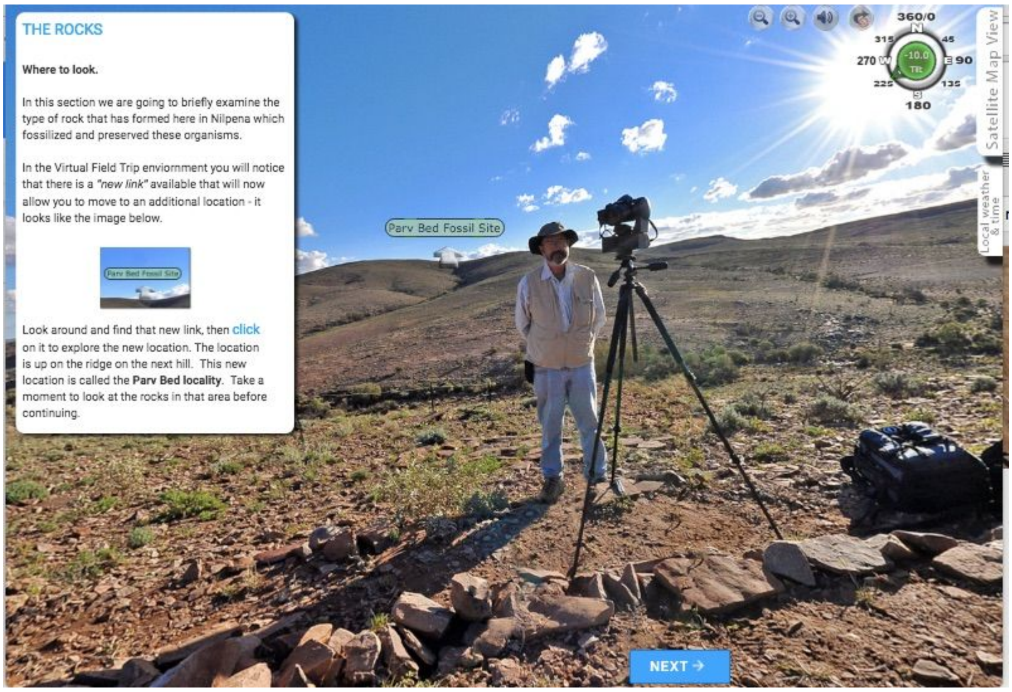
This screen introduces students to the concept of “Deep Time” with event markers that help students make chronological sense of when the Ediacaran period was in respect to the other time periods.

Deep time timeline activity (Screen 24)



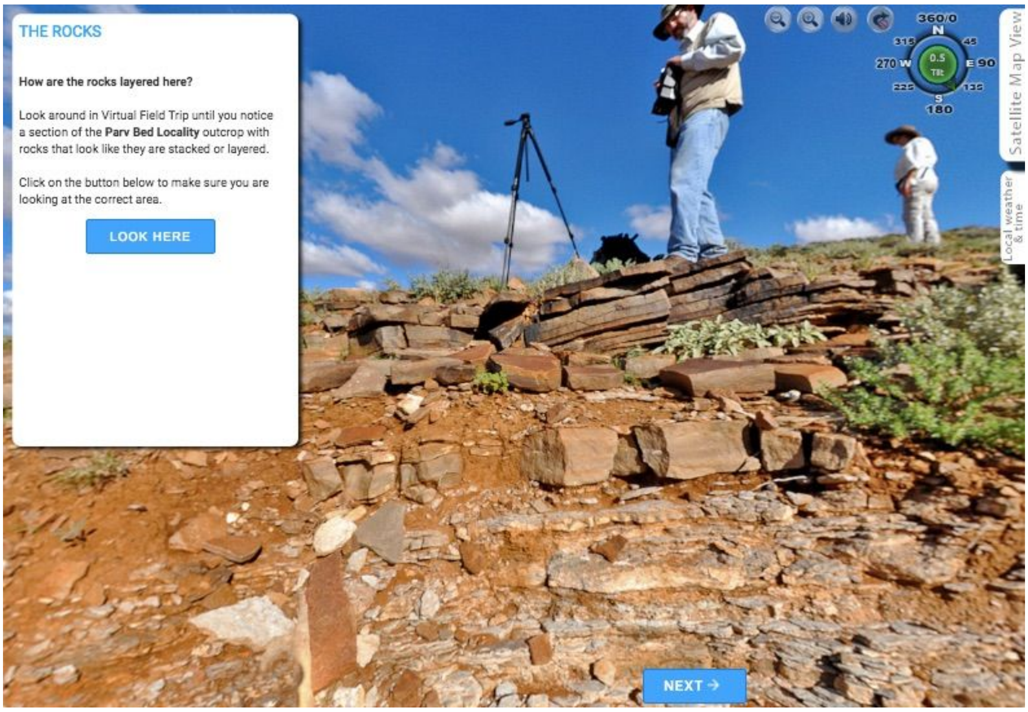
Using the information presented on the previous slides about Deep Time, students are to arrange the events in chronological order.

3. Where to Look: Parv Fossil Bed Exercise (Screen 27)



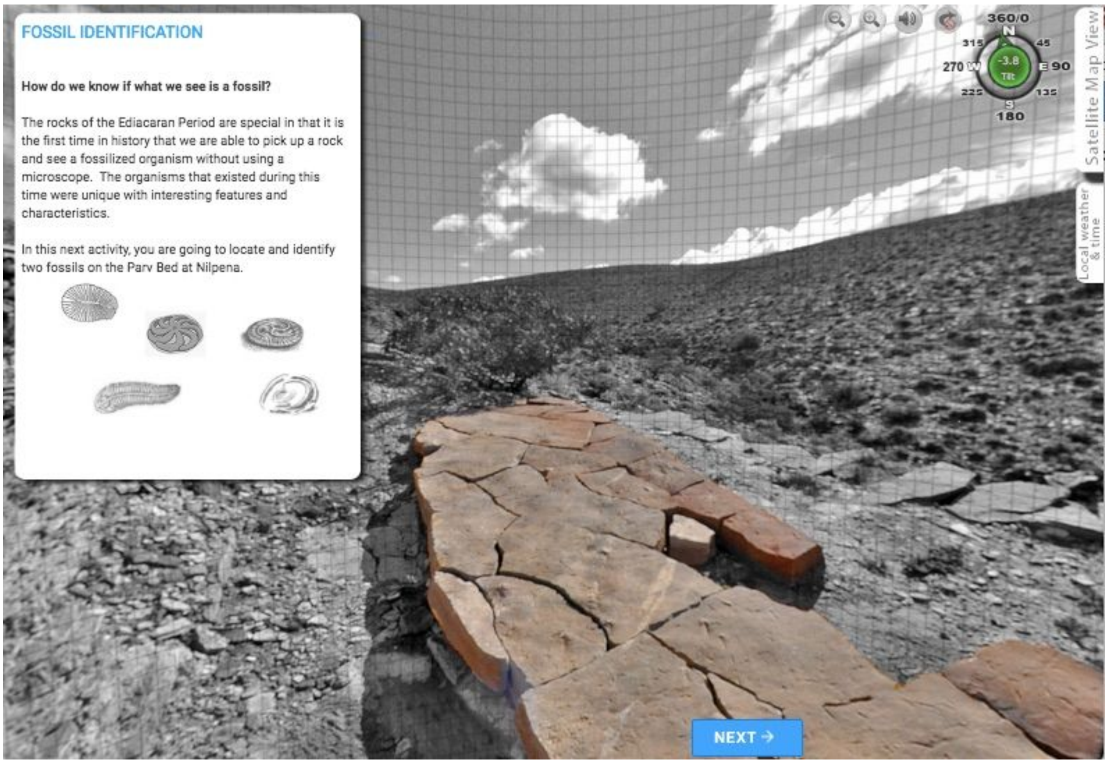
On this screen students must learn to navigate the 360 panoramic view of the Flinders Range and are tasked with locating the Parv bed fossil site (marked by a labeled moving arrow).

Investigating Rock Layers (Screen 29)



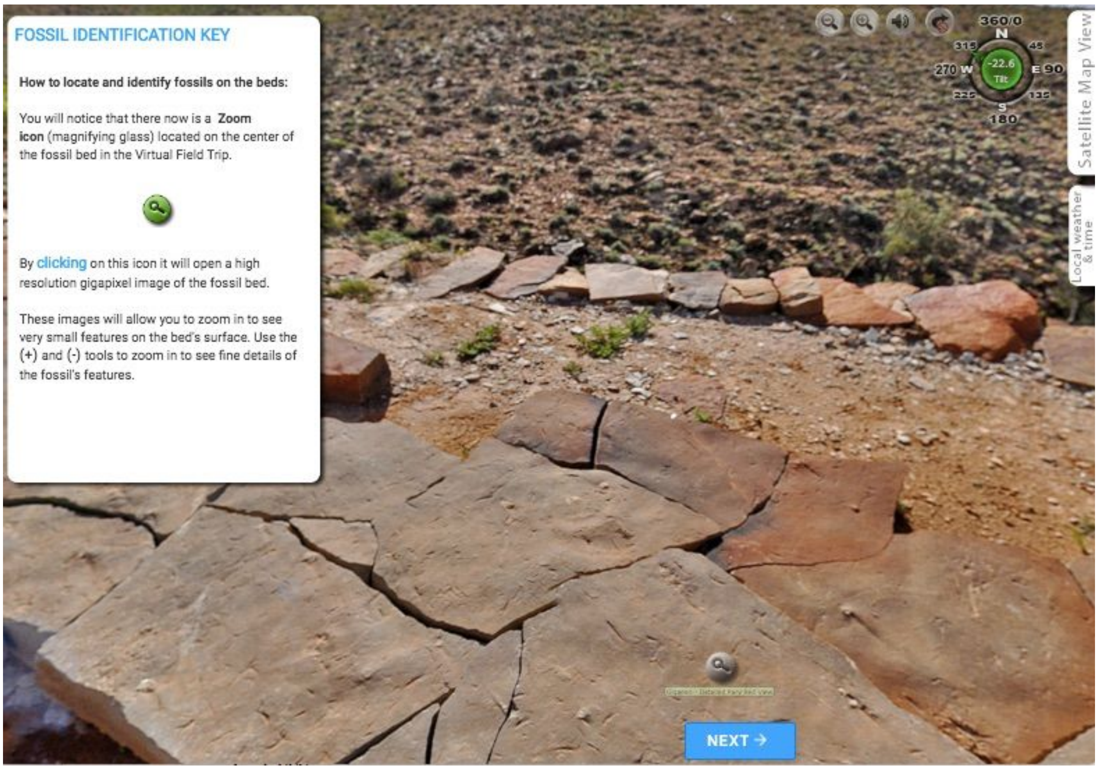
After clicking the moving arrow for the Parv fossil bed students are shown a stack of rocks where the fossils are found. This is the first of three fossil beds in the lesson and serves to introduce students to navigating the learnspace while also asking relevant questions.

Taking a Closer look at the Parv Fossil Bed (Screen 45)

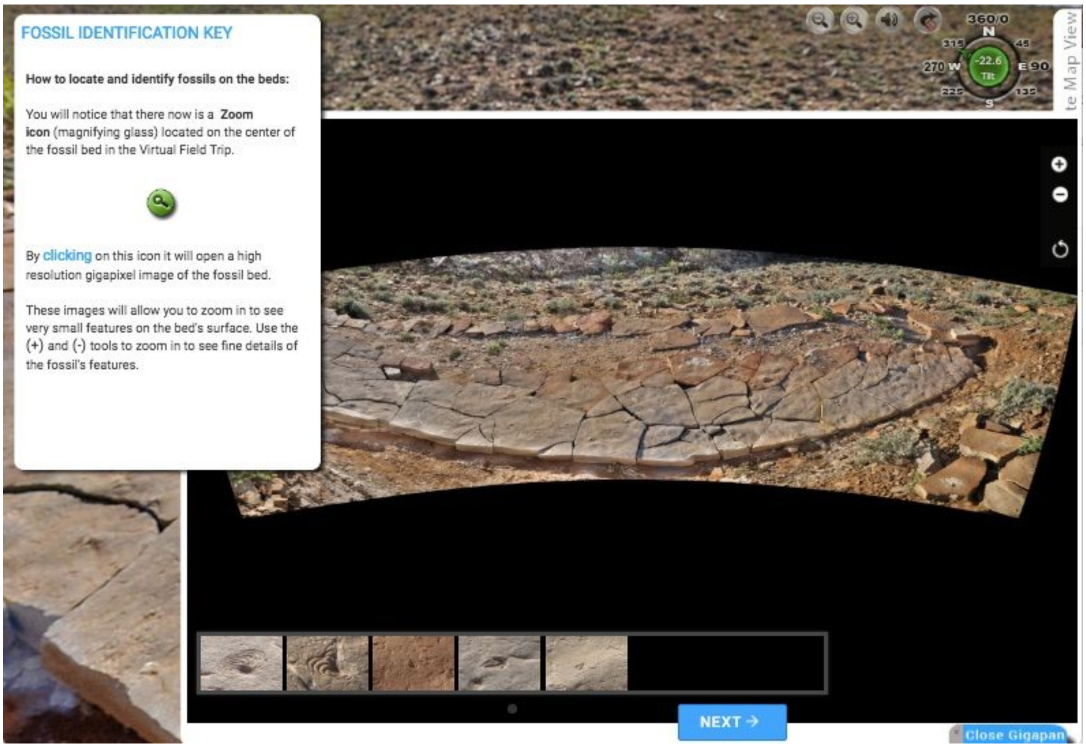


On this screen students will for the first time in this lesson actively inspect a fossil bed (Parv) and determine the kind of fossils they find.

Screen 47

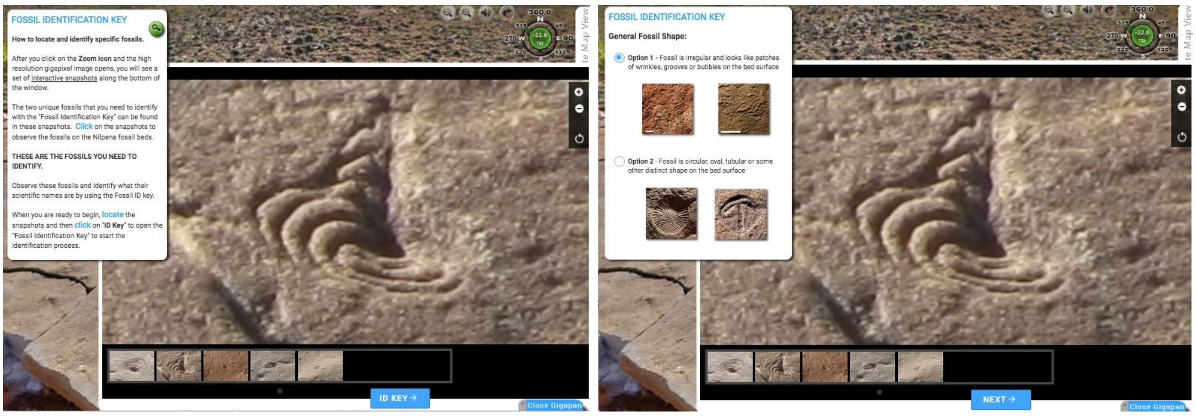


Students must practice moving the screen in order to locate the magnifying glass icon. Clicking this icon will take them to a screen where they can identify the fossil types present in the Parv fossil bed.



When a student selects the magnifying glass they are brought to a screen displaying the various fossils in the Parv fossil bed.

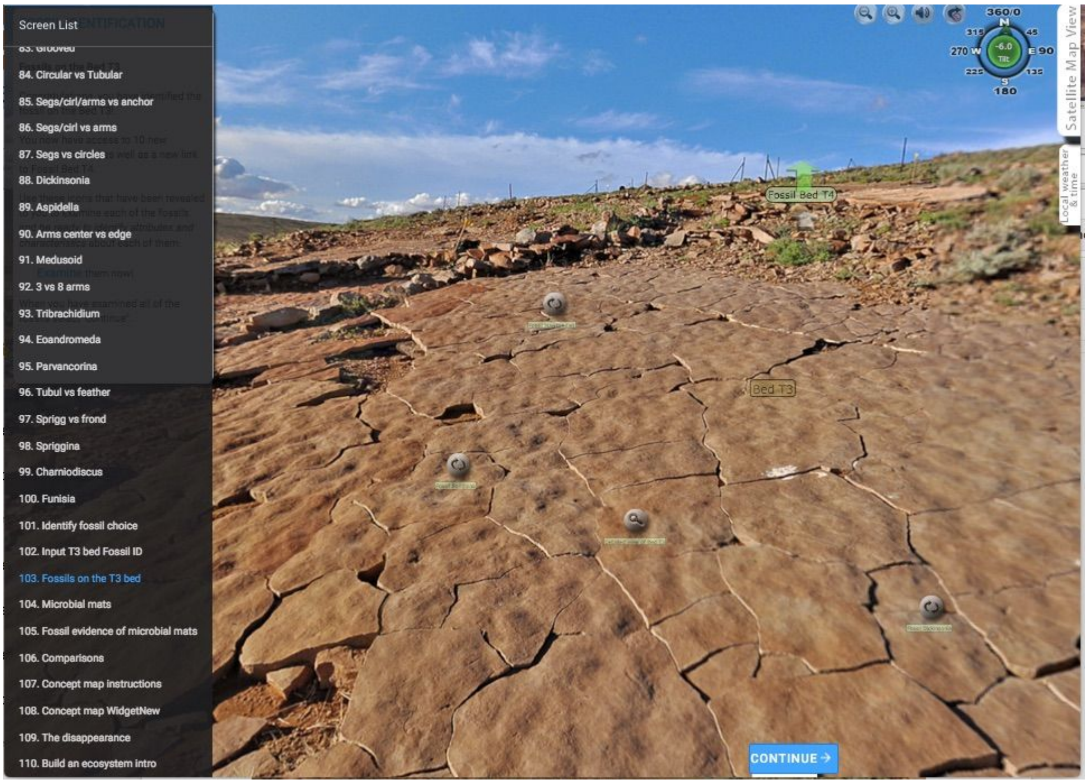
Screen 50



When a student clicks on a picture of a fossil they are brought to a screen where they can use their observational skills to identify the fossil.

4. T3 Fossil Bed (Screen 76)

Once students finish identifying fossils on the Parv fossil bed they are prompted to explore the T3 fossil bed where they will follow the same steps for fossil identification.

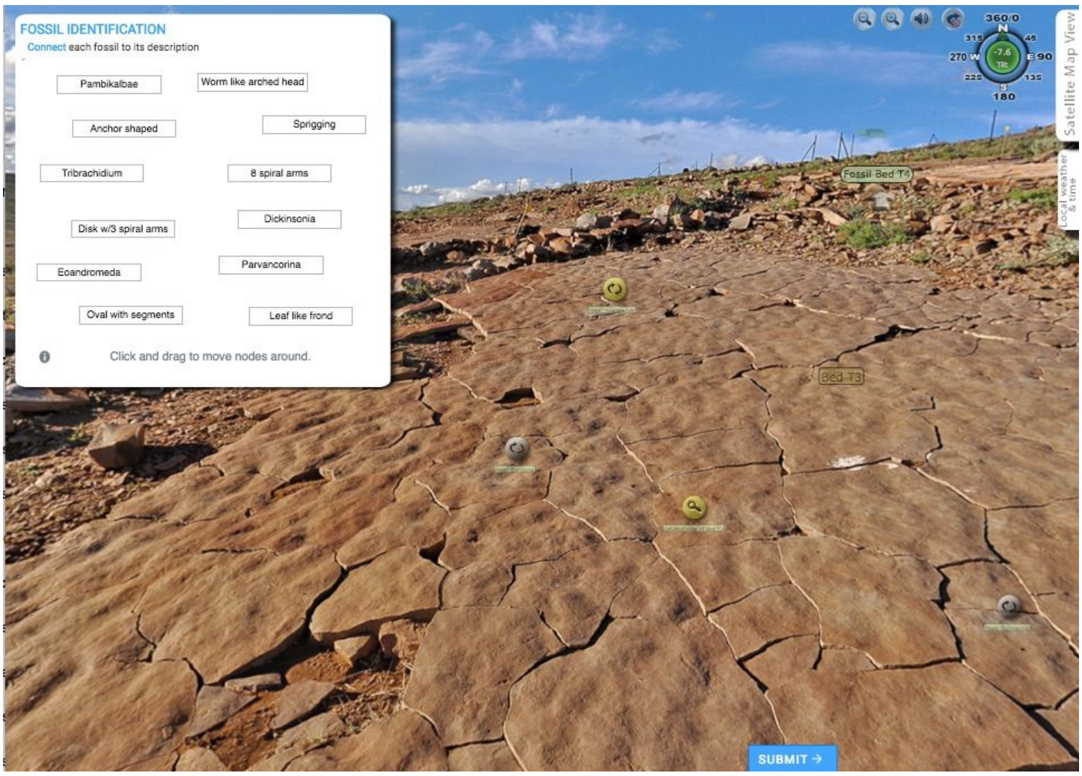


Once on the T3 fossil bed, students will click each individual magnifying glass in order to view the fossils that are within the rock layers and make observations about those fossils.

5. T3 fossil bed to T4 fossil bed

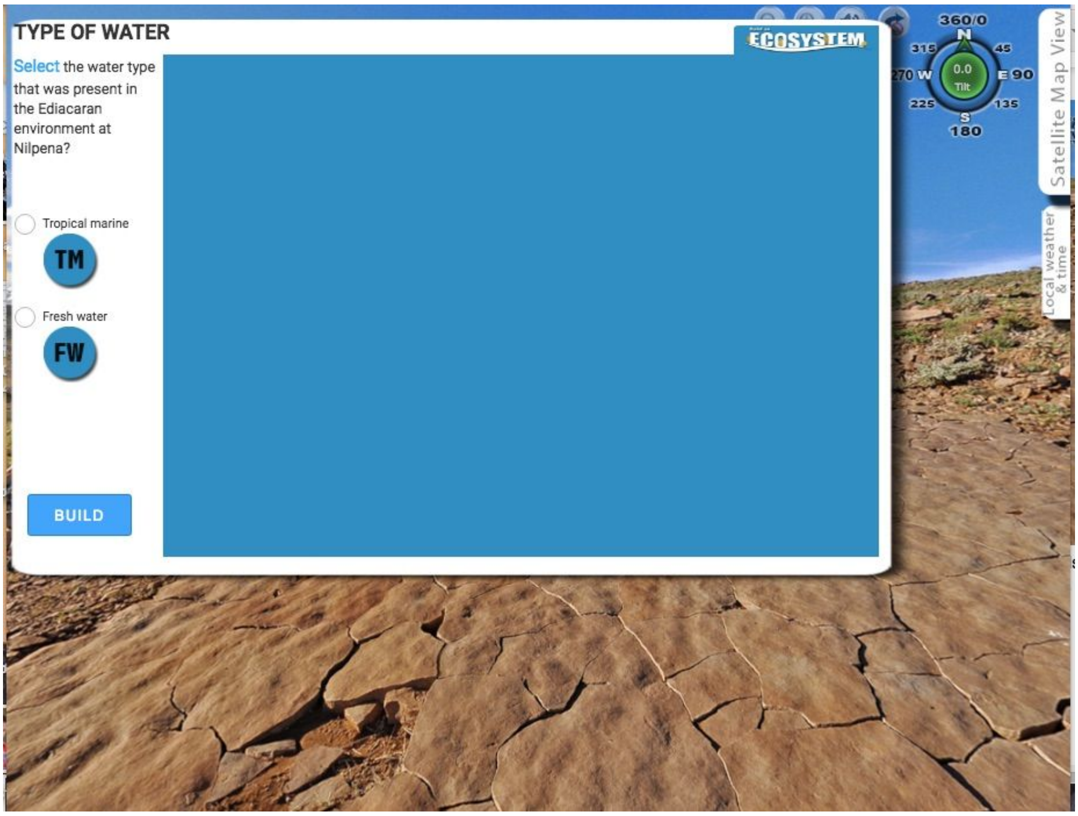
After clicking the moving green arrow for the T4 fossil bed, students are brought to a screen where they can again continue to explore what fossils are present in the rock layers by selecting the magnifying glass.

Fossil Concept Map (Screen 108)

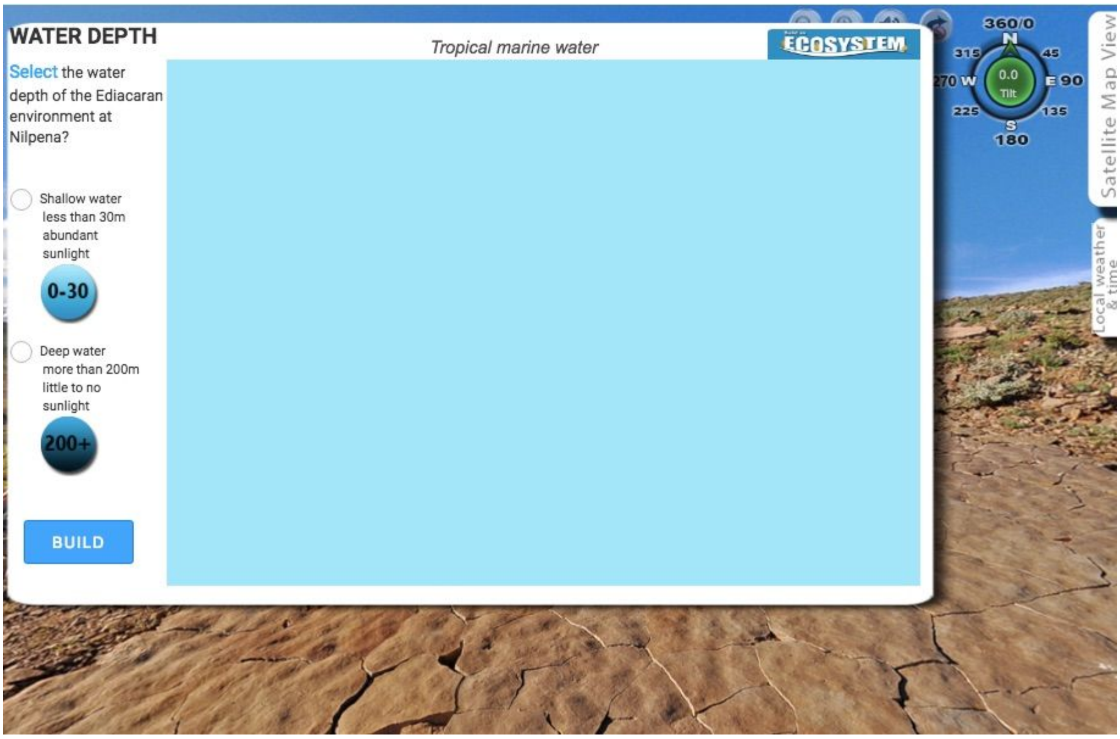


On this screen students will apply what they have observed about the fossils across several fossil beds and match the descriptions of the fossils to their names. If students forget they can always go back and review the fossils they encountered.

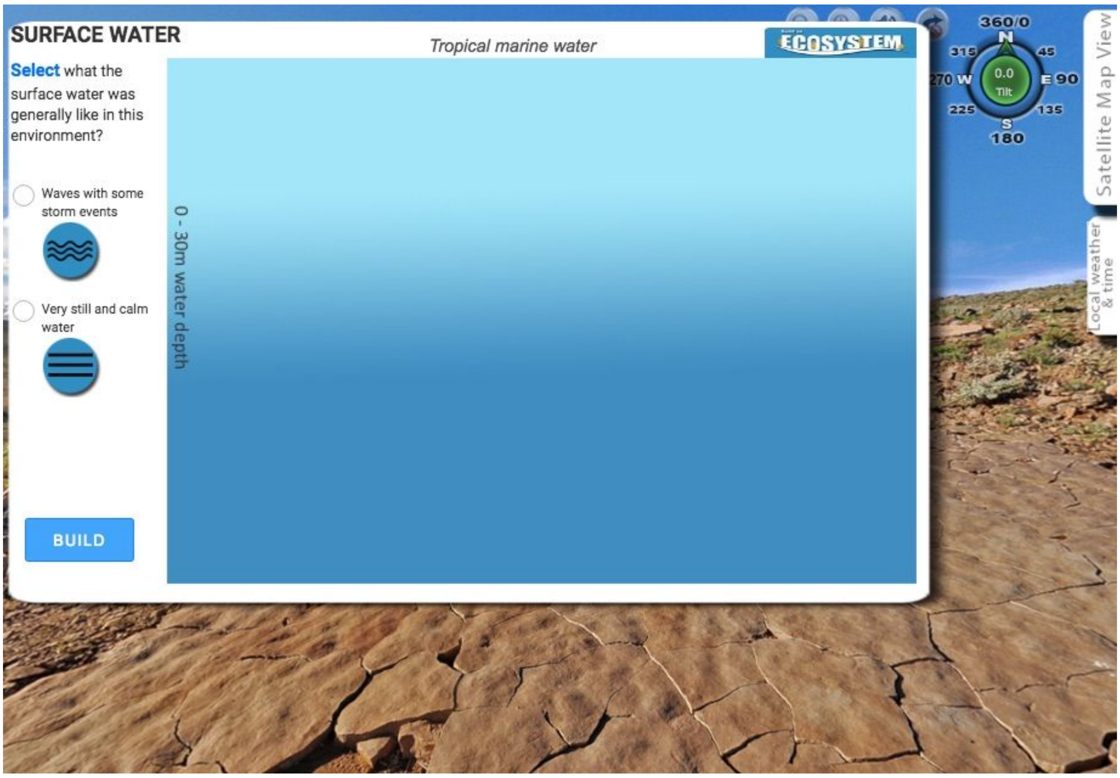
6. Build your own environment



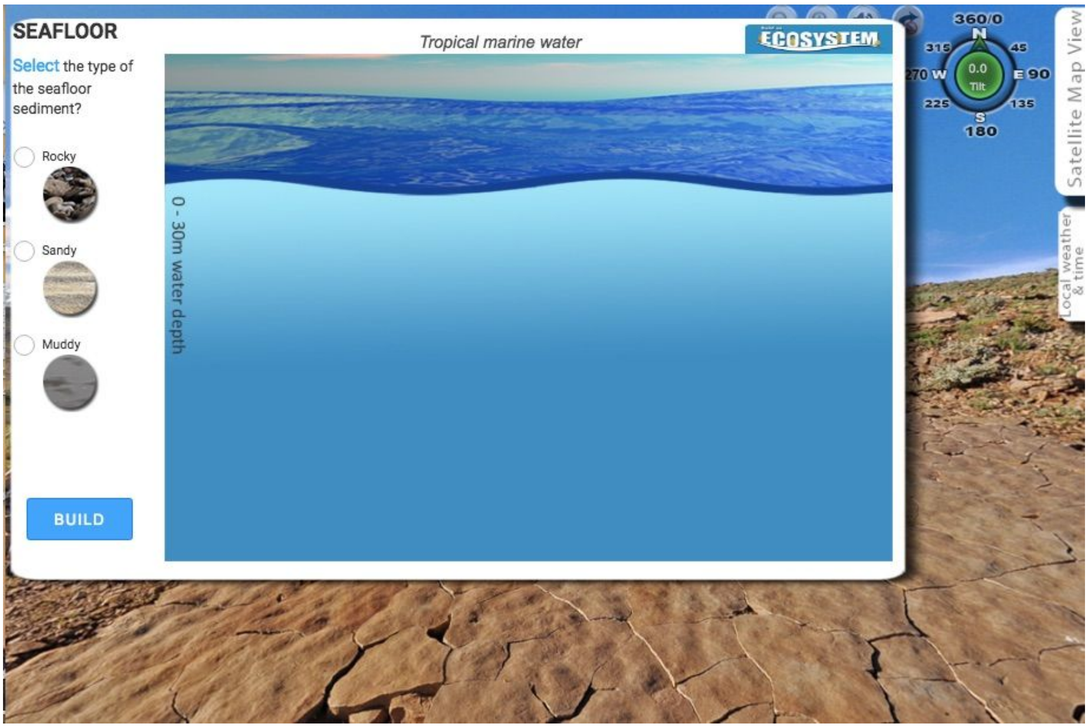
Here students have the opportunity to replicate the environmental conditions of the Ediacaran period by building their own ecosystem. The first condition students can manipulate is the type of water (tropical marine or freshwater) their ecosystem will contain.



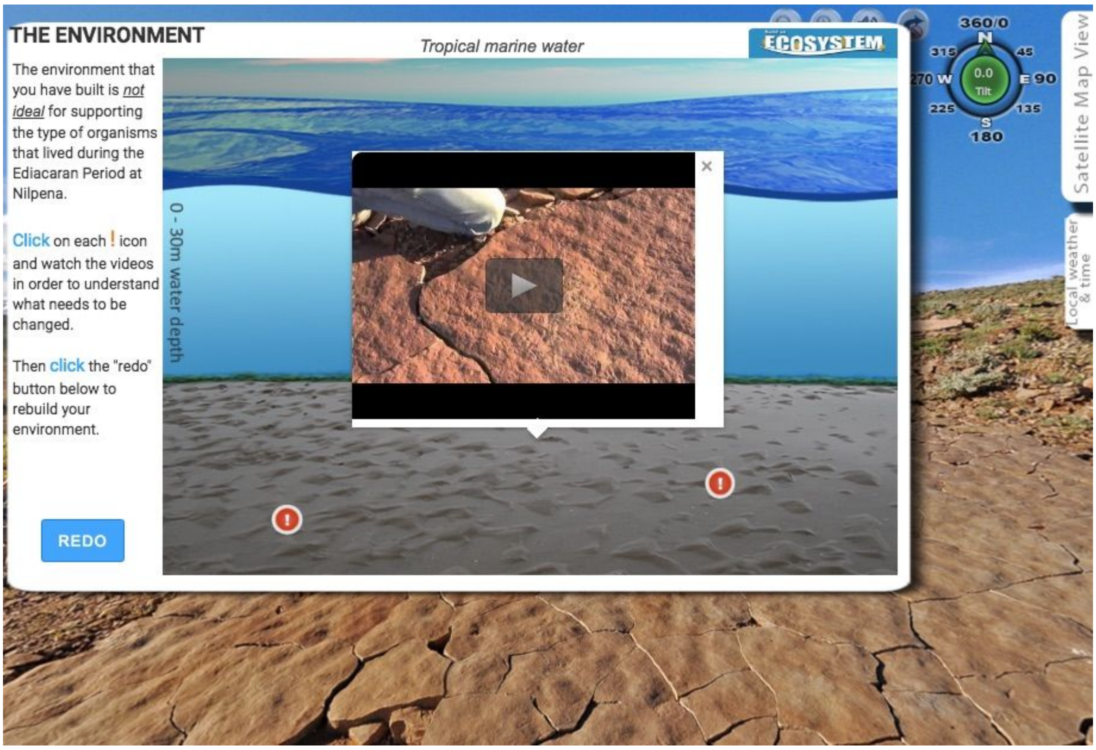
The second condition students can manipulate in their ecosystem is the depth of water (shallow or deep).



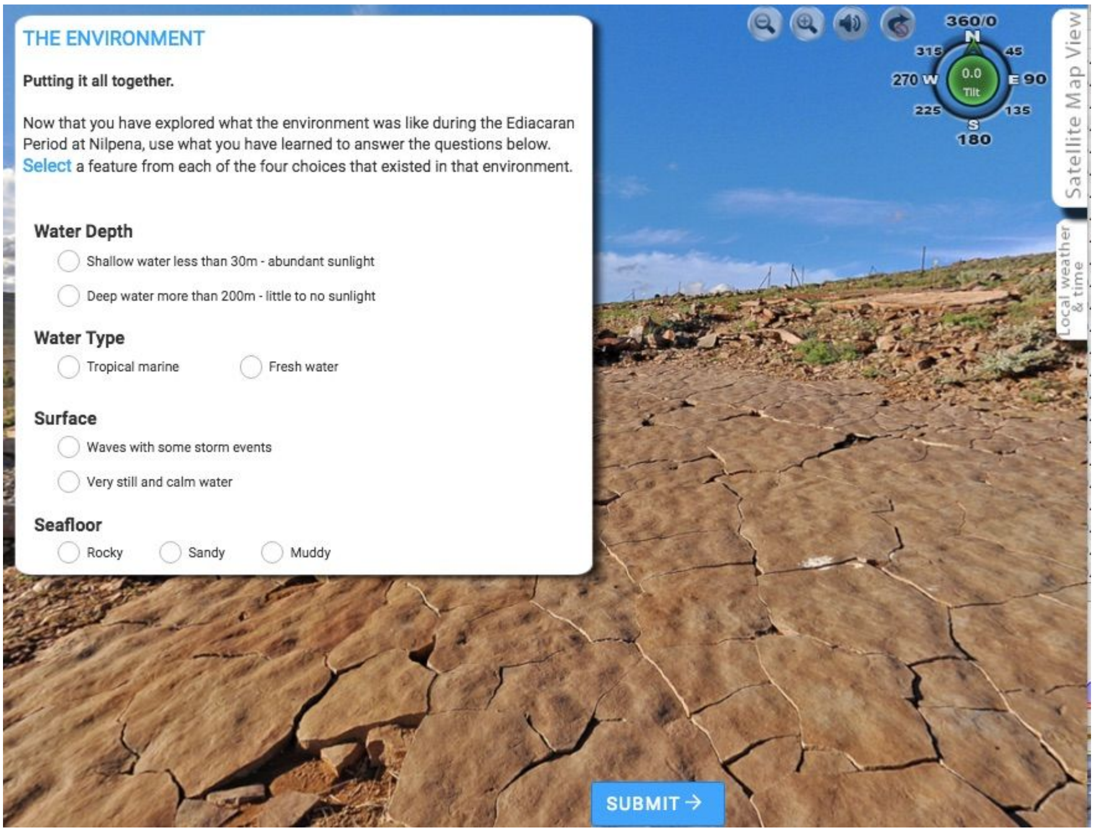
The third condition that students can manipulate is how turbulent the surface of the water is (waves with some storm events or still and calm water).



The fourth condition students can adjust is the composition of the seafloor (rocky, sandy, or muddy).



If the environmental conditions selected by students do not match with the conditions of the Ediacaran period, students should rewatch the informational videos from earlier slides that are conveniently provided and marked by exclamation marks. The information provided in these videos will guide students in selecting the correct conditions for replicating the Ediacaran ecosystem.



After successfully building an environment resembling the Ediacaran period, students must answer the following questions to review the conditions they found were conducive to making such an environment. Answering these questions again allows the student to compare their previous assumptions with what they learned throughout the course.

Unit 4 Time Traveller’s Guide to Life on Earth — First Signatures of Life: North Pole, Australia

Lesson Stats

- Average time spent: 1-2 hours

Learning Objectives

- See Instructor's Guide

Assessment

Max score: 52

Lesson Flow

- Welcome, Screen 2
- Orientation, Screen 3
- North Pole Dome, Screen 4
- Age of the Rock, Screen 5
- Review Life of Nilpena, Screen 6
- Explore, Screen 8
- Identifying Signs of Life, Screens 10-15
- Explore Again, Screen 16
- Are There Others Here?, Screen 17
- Stromatolites, Screens 22-25
- North Pole Conclusion, Screen 26
- The Final Chapter, Screen 32

Common Student Issues/Misconceptions

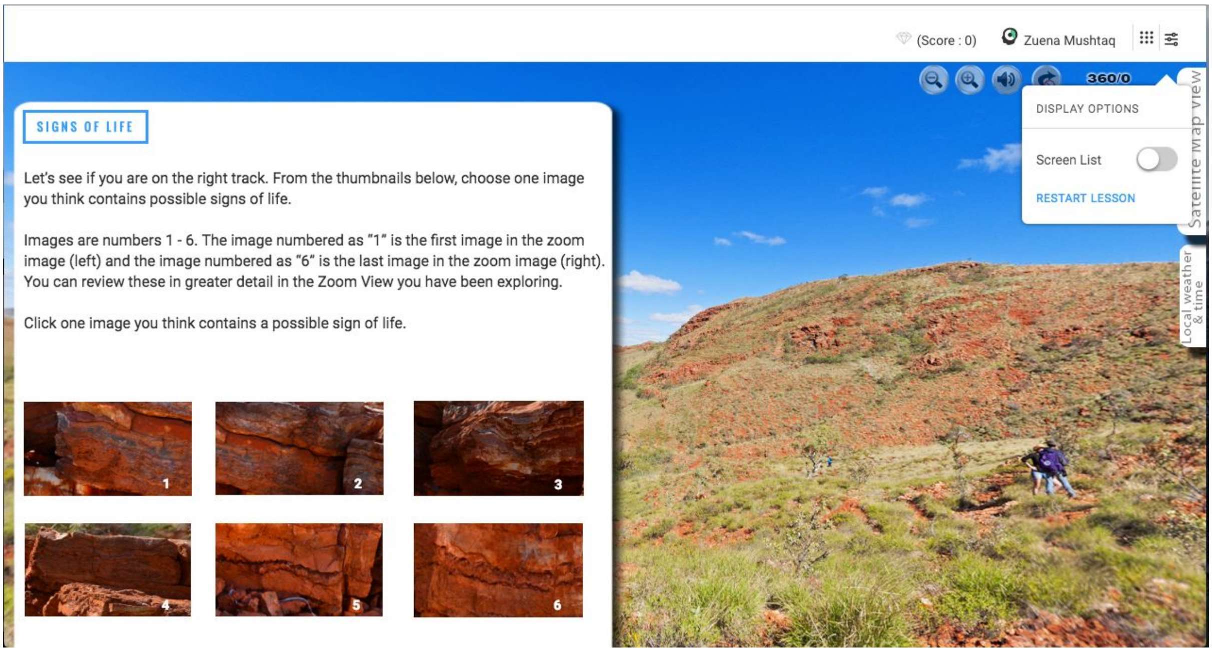
- Students often struggle with comparing stromatolite evidence to the surrounding geology, as it is not easily identifiable as biological compared to prior fossil evidence they have seen.

Activity Walk-through

1. Orientation, Screen 3

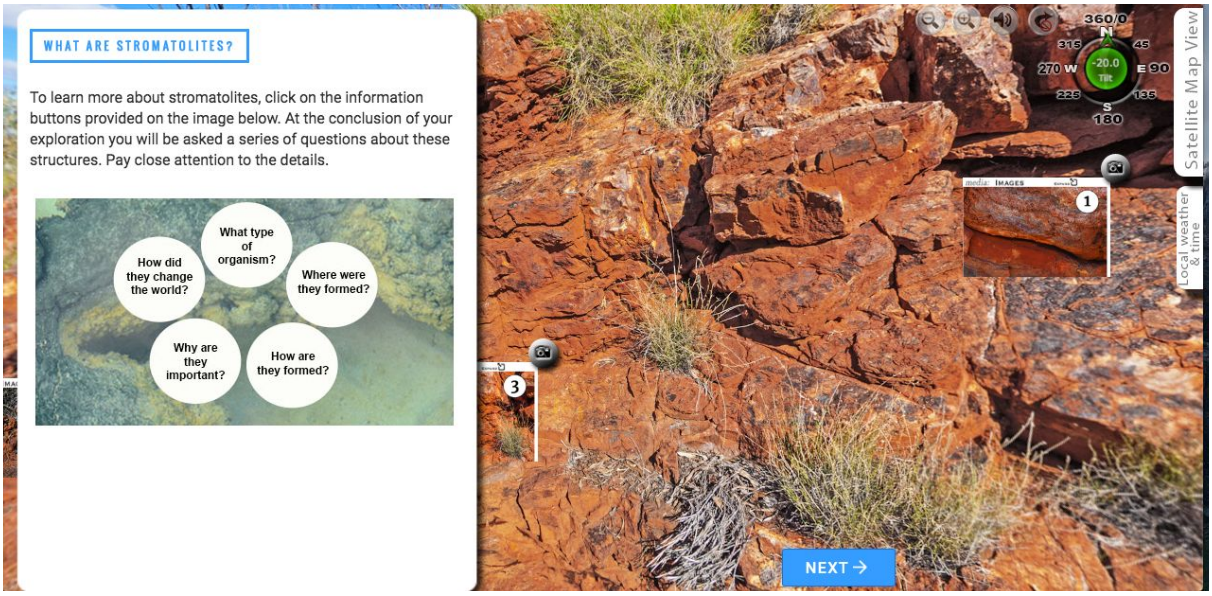
Students are taught how to navigate through this lesson by exploring the location. This slide is important as it helps students understand how to explore the slides, which is different from the lessons in the previous units. If students are having trouble with navigation, refer them to this slide.

2. Signs of Life, Screen 9



Students will be asked to choose which images shows possible signs of life and then asked questions based on their choice.

3. What are Stromatolites?, Screen 23



This slide gives a basic overview of stromatolites. Once students have finished their exploration, they will be asked questions regarding what they have read.

Unit 5 Into the Cell: Into the Animal Cell

Lesson Stats

- Average time spent: 45 minutes - 1 hour

Learning Objectives

- See Instructor's Guide

Assessment

Max score: 650

Lesson Flow

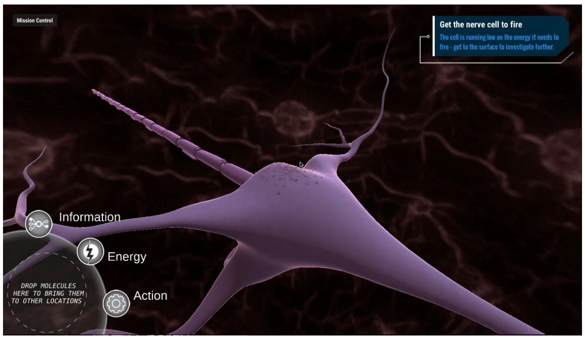
- Introduction, (Screens 1-2)
- Intro video of volleyball player jumping, (Screen 3)
- Animal nerve cell interactive including cell map, (Screens 4-5)
- Representations Lessons, (Screens 6-10)
- Conclusion/Feedback, (Screens 11+)

Simulations

Nerve cell simulation

Activity Tutorial

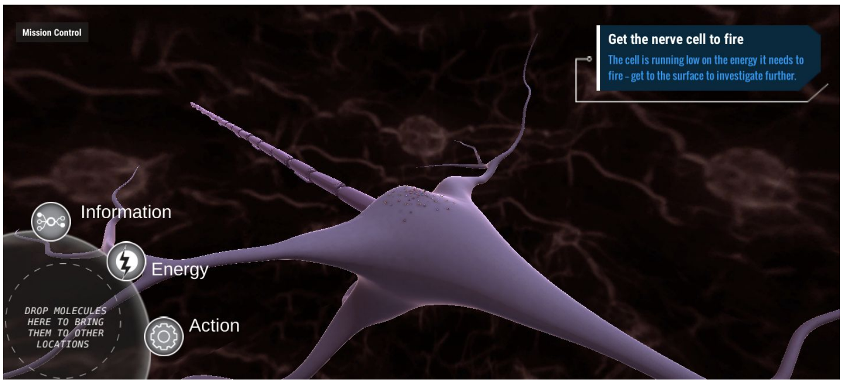
1. Animal cell simulation



See this tutorial video for an introduction to the interactive unit and how it functions.

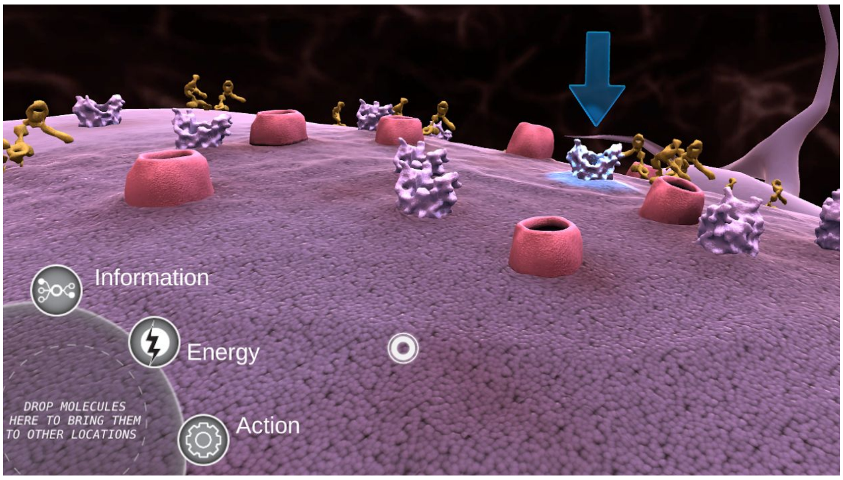
Students will be tasked with exploring an animal cell and using functional units to make actions occur within the muscle cell. The goal of the lesson is to help students conceptualize the processes that occur within a cell and how they contribute to the macroscale actions of a volleyball player.

a) View from afar before students click onto the smaller elements.

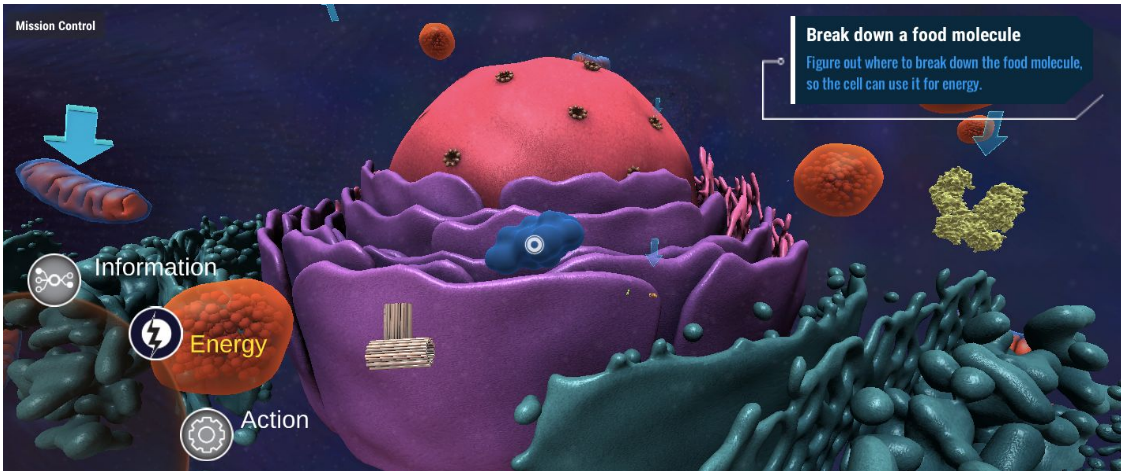


b) Students are to click and drag the glucose food molecule (blue) into the glucose channel (marked with a blue arrow) to begin the journey.

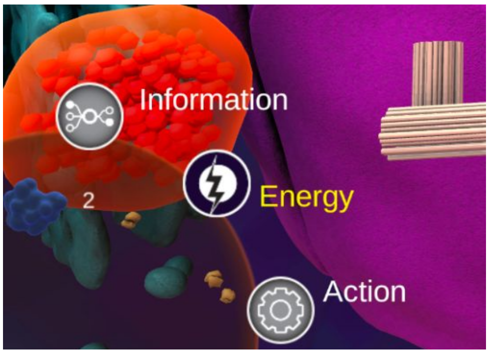
c) After the glucose enters, click the blue arrow to follow it inside the cell.



d) View from inside the cell as active processes occur all around the viewer.

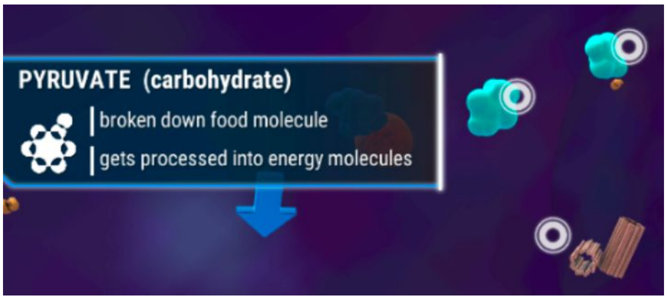


e) Once inside, click and drag the food molecule to the inventory (bottom left) to save it for later use.

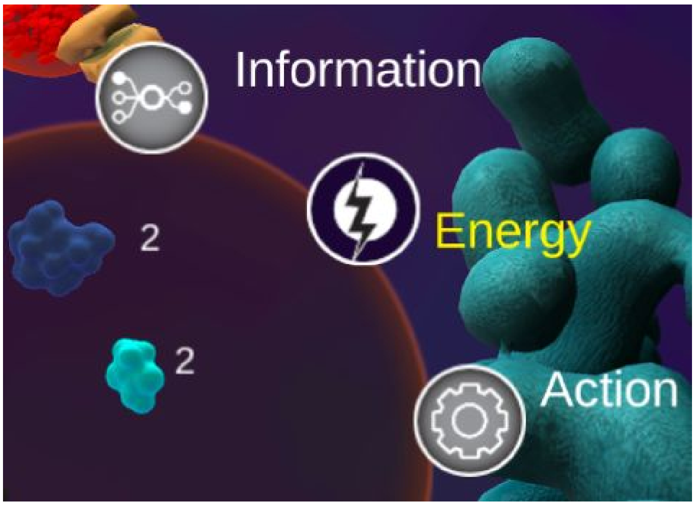


f) Breakdown the food molecule (blue) at the glycolysis enzyme (light green molecule shaped like a Y) by dragging it onto the enzyme.

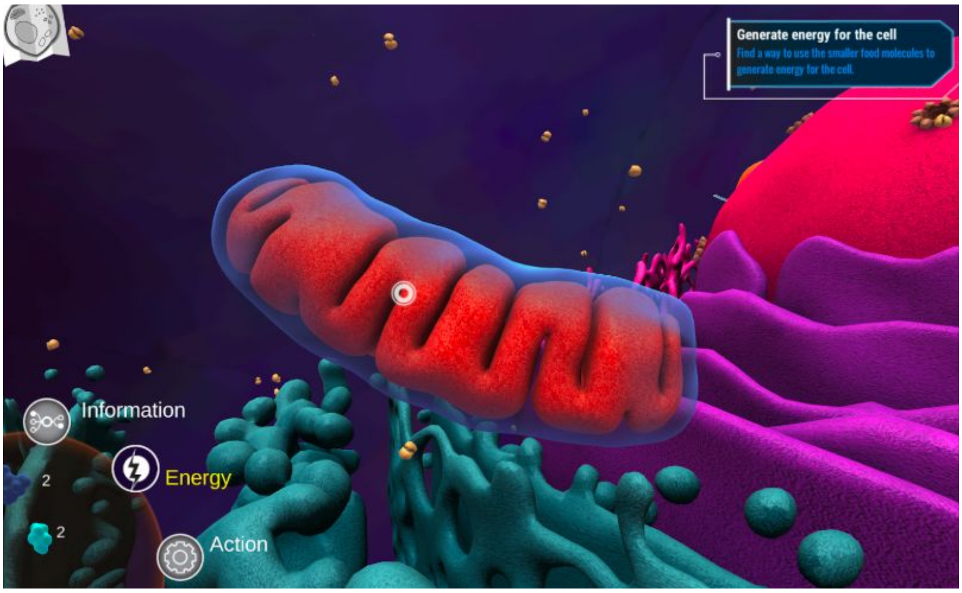
g) Breaking down the glucose will give 2 pyruvate molecules (light blue).



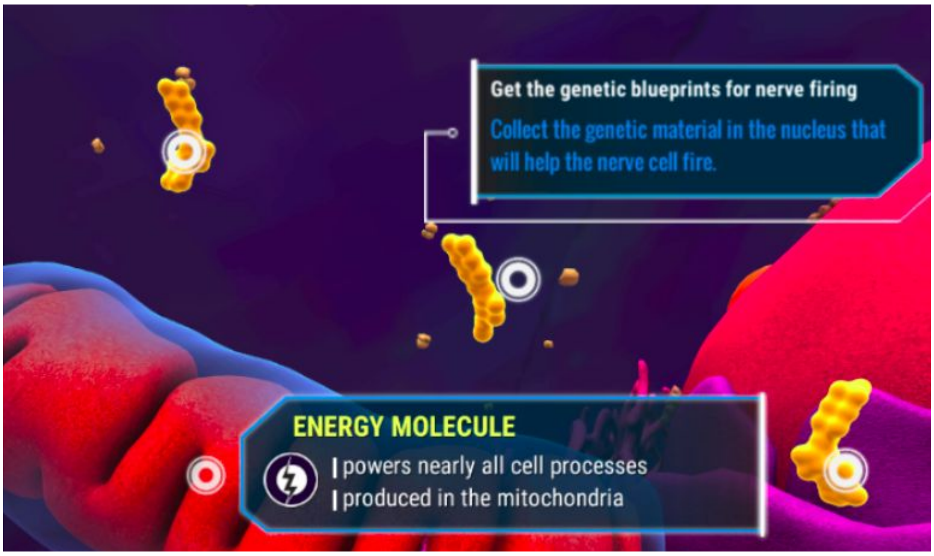
h) Save the 2 pyruvate molecules into your inventory.



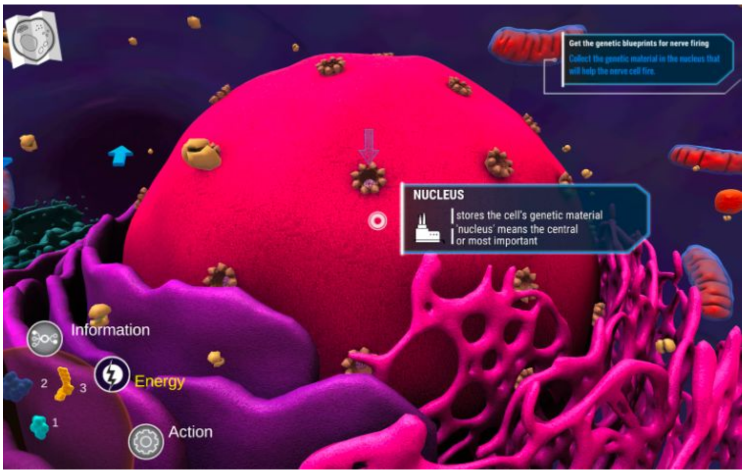
i) Find the mitochondria (red structure) and drag the pyruvate onto the mitochondria to break it down into ATP energy.



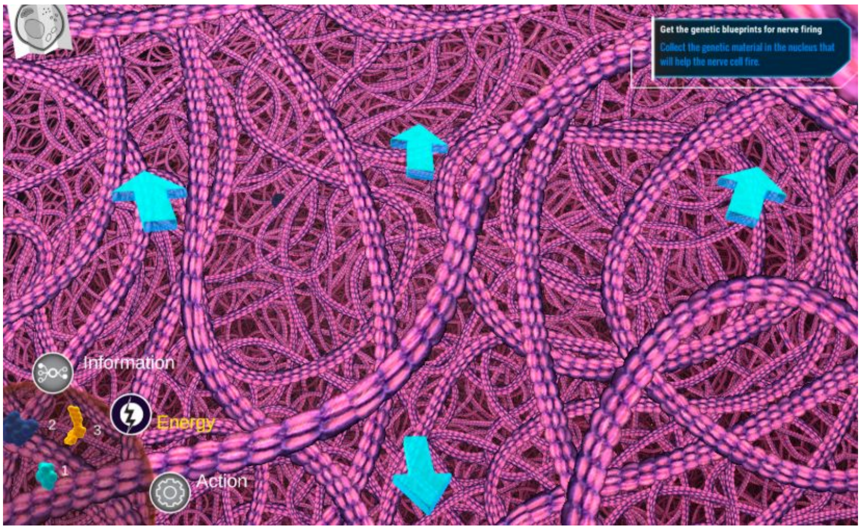
j) Collect the three ATP energy molecules (yellow molecules) and drag them into your inventory for later use.



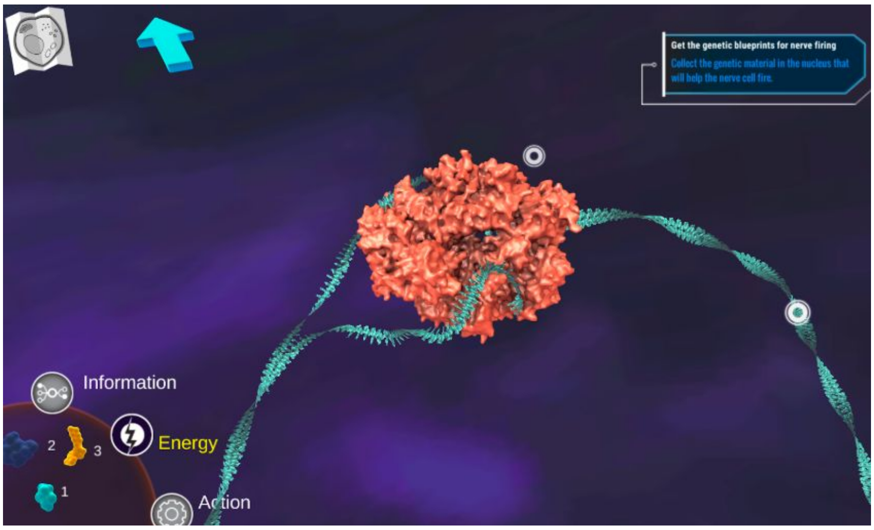
k) To collect the genetic material, go inside the nucleus (large pink structure) by clicking on the blue arrow.

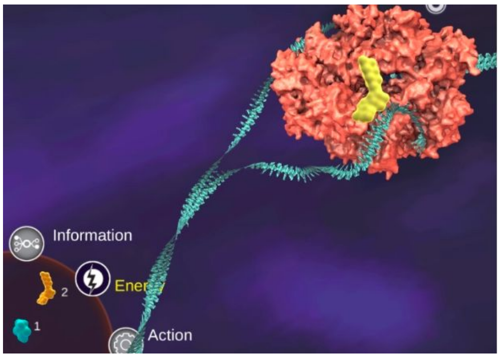


l) Once inside, click on the leftmost arrow to find the nerve firing protein DNA code.

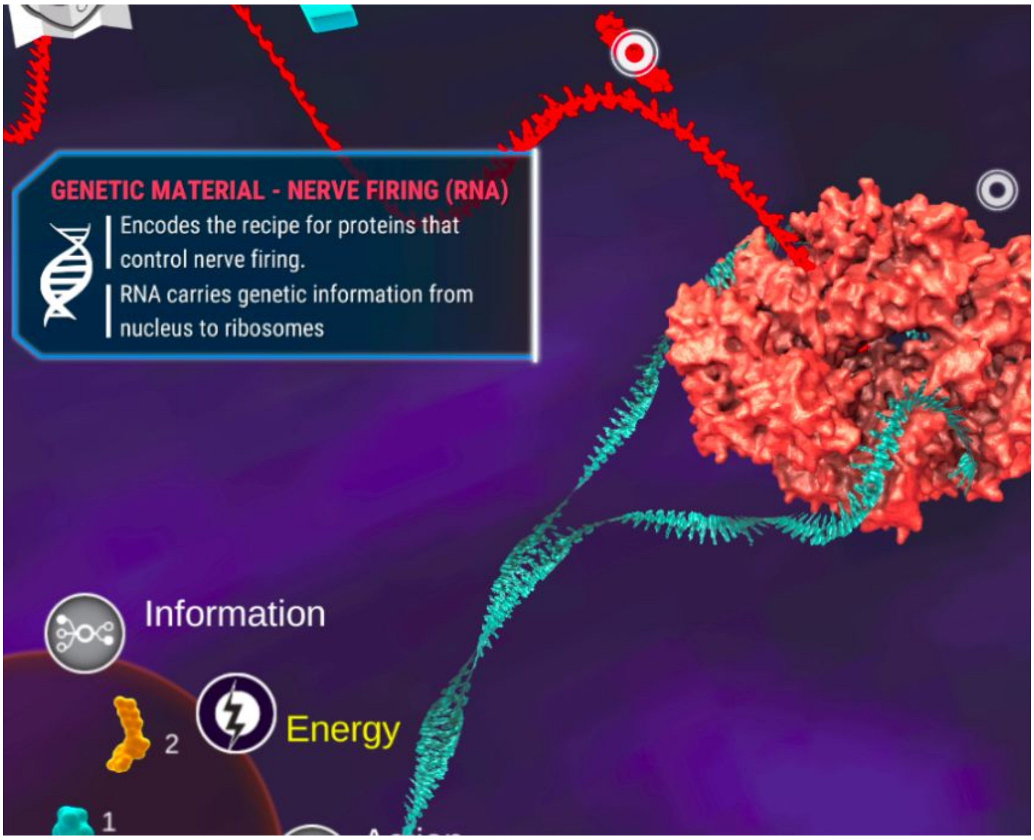


m) You will find the DNA strand connected to the polymerase enzyme (orange). Click and drag one ATP into the center of the enzyme to start making a RNA copy.

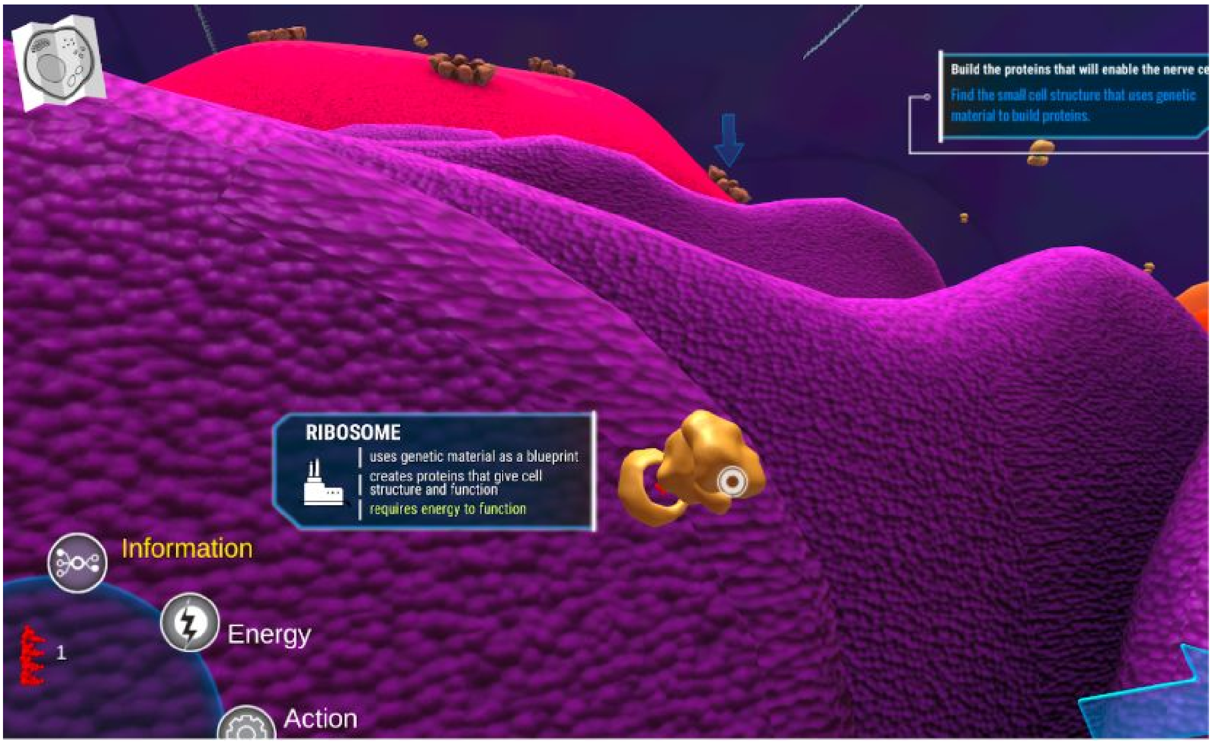




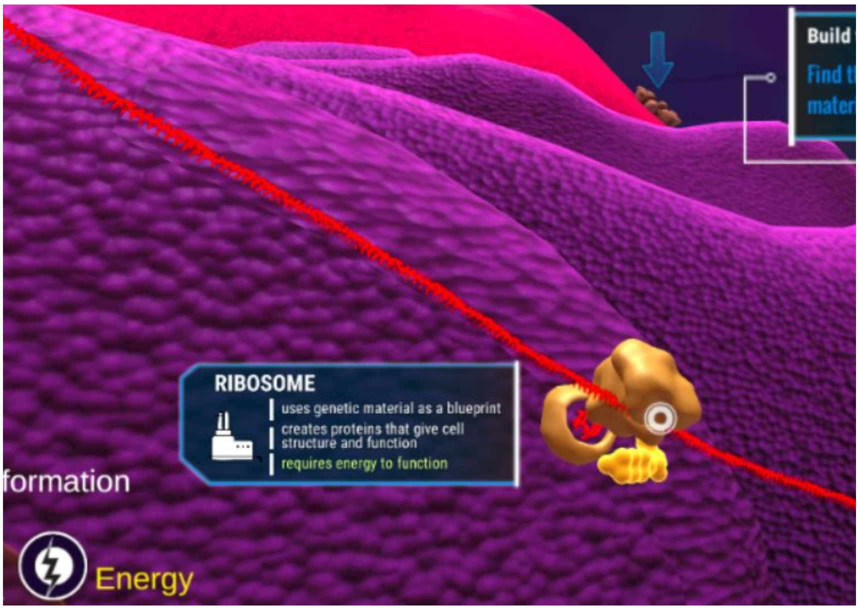
n) Collect the RNA copy of nerve firing protein and save it to your inventory.



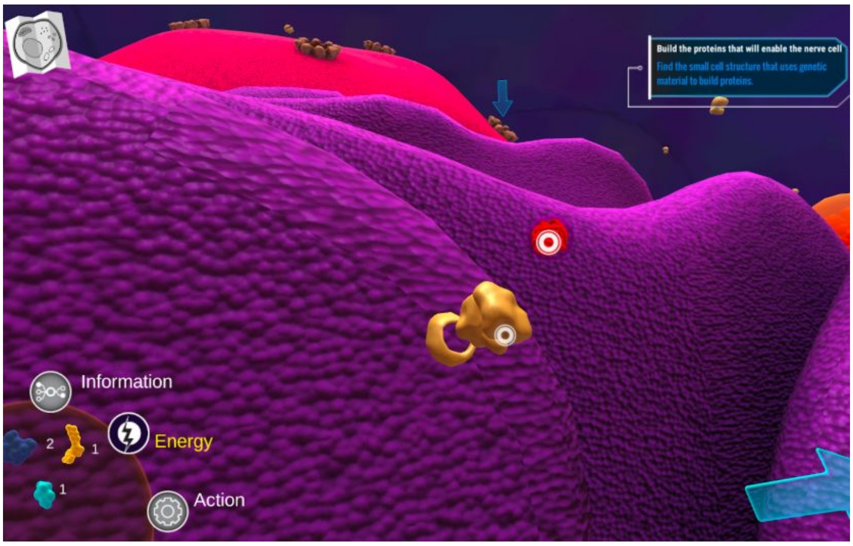
o) Next, exit the nucleus to find the ribosome.

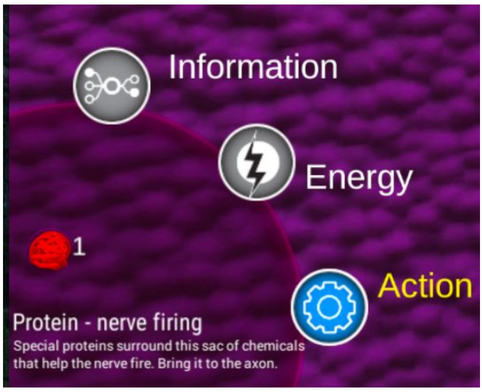


p) Give the ribosome the nerve firing RNA (red) AND one energy molecule saved from before (yellow).



q) This will produce the nerve firing protein (red ball shaped molecule). Collect the nerve firing protein and place it in your inventory.

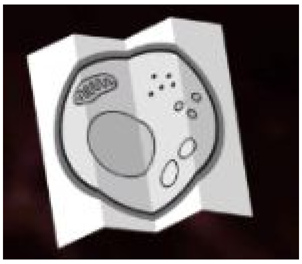


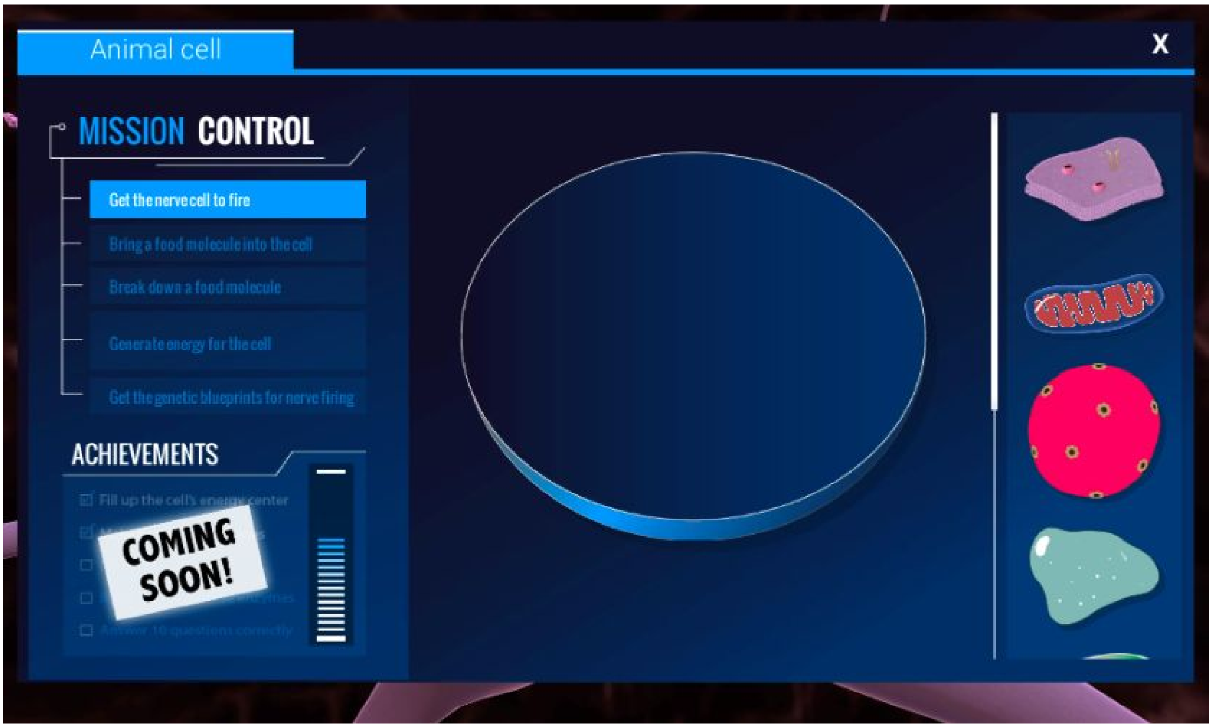


r) Go to axon tunnel, click and drag the nerve firing protein to release it into the axon.

IMPORTANT!

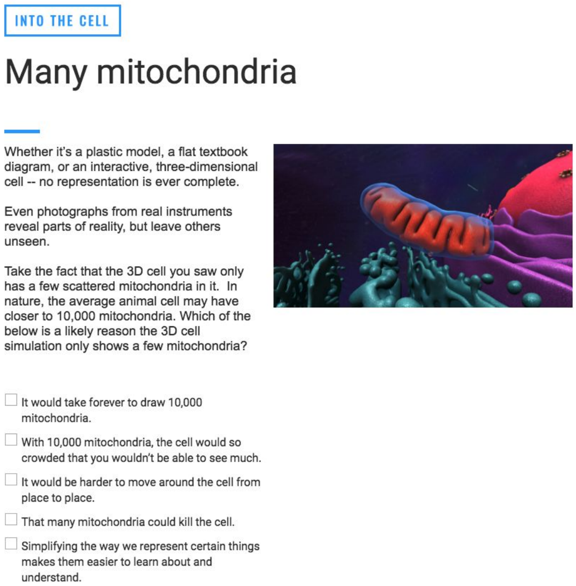
Before finishing the simulations student must complete the animal cell map.





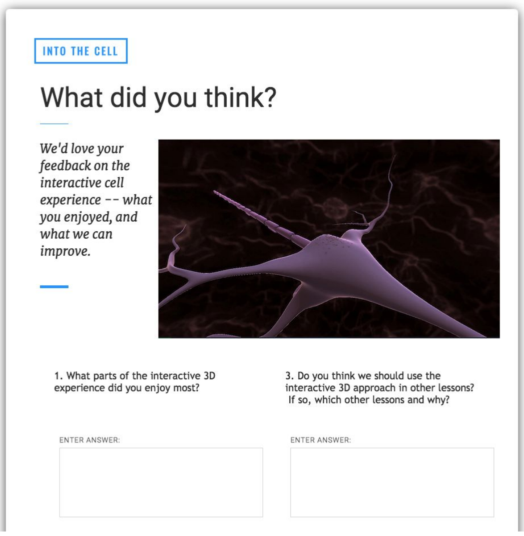
- It should be noted that this section of instruction is graphically intensive and using a Chrome browser on a PC/Mac is the best setup for fluidity in the animations. Students with computers that are not up to date on all updates may find themselves unable to complete the lesson.

2. Representation lessons -- what are the strengths and limitations of a 3D simulation like the one we included?



This set of screens asks students to consider how the 3D simulation is a representation that diverges from reality in order to facilitate learning. And that all visualizations have strengths and drawbacks.

3.Feedback screen - we ask students to answer a few questions about the quality of their learning experience.



Unit 5 Into the Cell: Into the Plant Cell

Lesson Stats

- Average time spent: 20 minutes

Learning Objectives

- See Instructor's Guide

Assessment

Max score: 100 points for completion of plant cell map

Lesson Flow

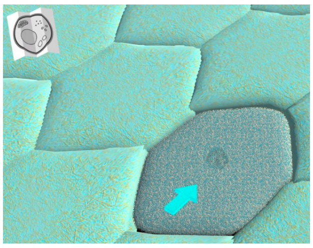
- Plant cell simulation exploration
- Completion of plant cell map

Simulations

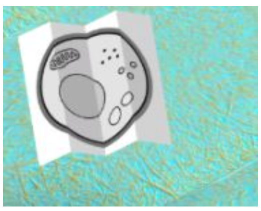
Plant cell simulation

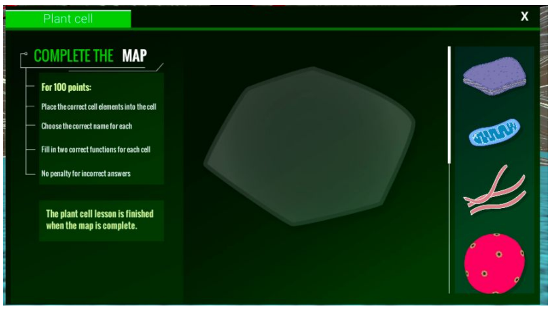
Activity Tutorial

1. Students will freely explore the plant cell and learn what organelles are present.



2. Students will open the cell map as they move through the plant cell (100pts).





Unit 5 Into the Cell: Into the Bacterial Cell

Lesson Stats

- Average time spent: 20 minutes

Learning Objectives

- See Instructor's Guide

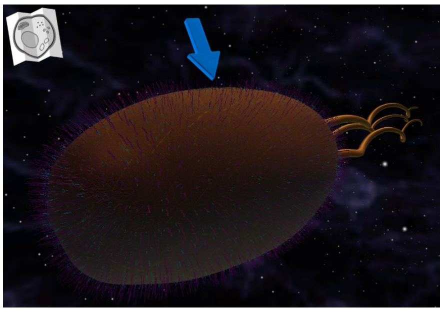
Assessment
Max score: 100 for completion of bacterial cell map

Lesson Flow
- Bacterial cell simulation exploration
- Completion of bacterial cell map

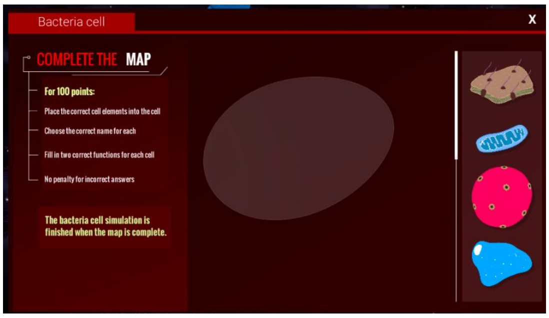
Simulations
Bacterial cell simulation

Activity Tutorial

1) Students will freely explore the bacterial cell and learn what organelles are present.



2) Students will open and complete the cell map as they move through the cell (100pts).



Unit 6 Searching for Signatures: The Chemical Basis of Life

Lesson Stats
- Average time spent: 1-2 hours

Learning Objectives
- See Instructor's Guide

Assessment
Max score: 174

Lesson Flow

- Introduction, Screens 1-2
- The Atom, Screens 3-6
- Atomic Structure and Summary, Screens 7-18
- Elements and Atomic Bonds, Screens 19-22
- Polymers, Screens 23-27
- Cell Components, Screens 28-30
- Bond Review, Screen 31
- Polar/Hydrophilic Molecules, Screens 32
- Types of Bonds, Screens 33-36
- Reflection and Summary, Screens 37-38

Common Student Issues/Misconceptions

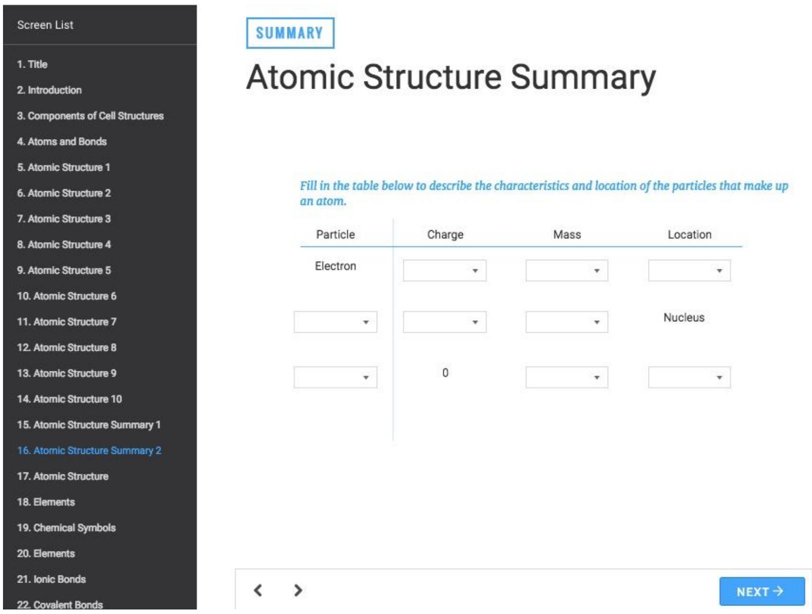
- Students sometimes have difficulty understanding the role charges play in bonding and polarity.

Simulations

NA

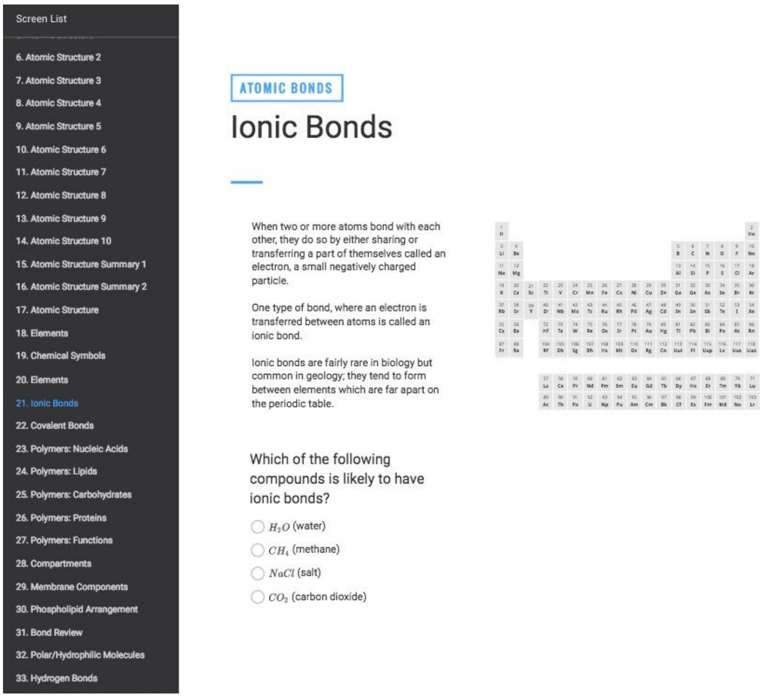
Activity Walk-through

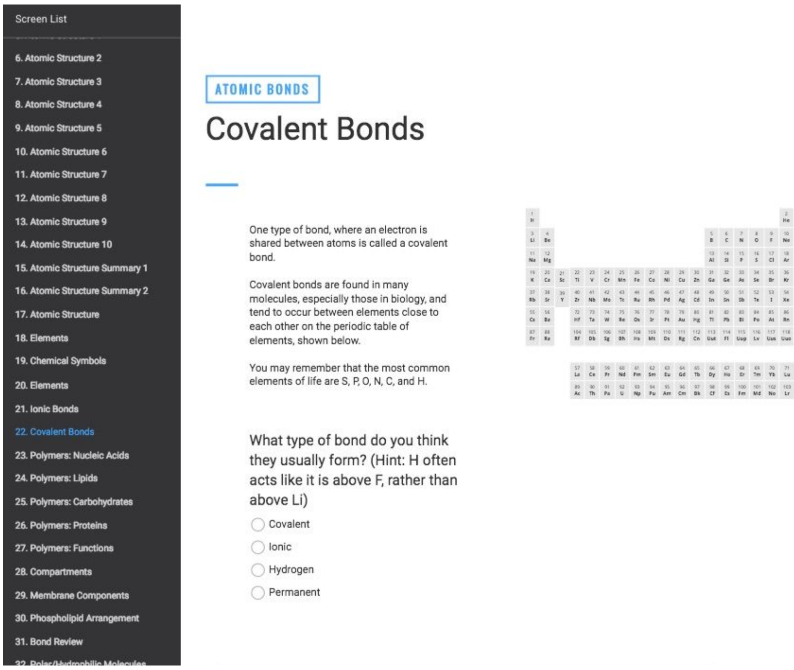
3. Matching Atomic Details (Screen 16)



On this screen students will apply what they learned about atomic structures and fill in the missing segments in the table.

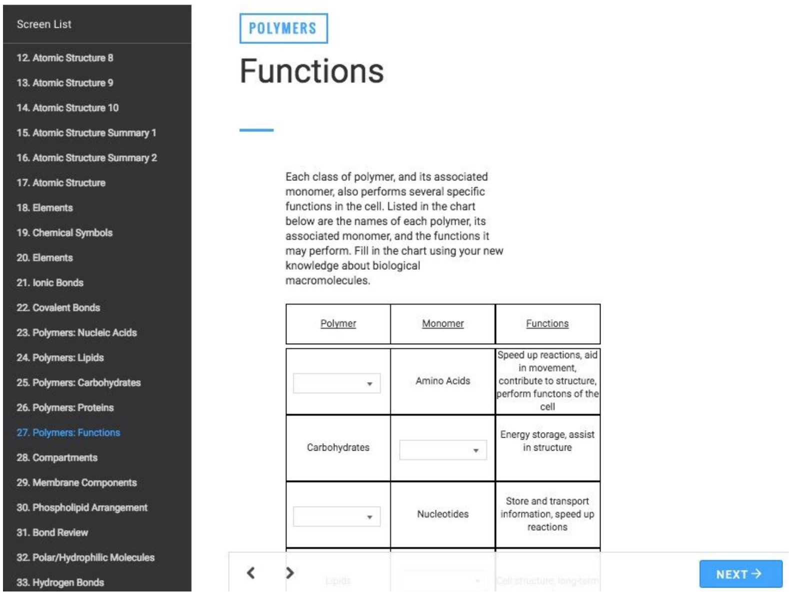
4. Ionic Bonds (Screen 21 and 22)





On this and the subsequent slide students will learn about ionic and covalent bonds which will be important in the following screens and the throughout the course.

5. Matching Polymer Functions (Screen 27)



In this activity students will apply what they learned about monomers and polymers and fill in this general table summarizing the primary points.

Unit 6 Searching for Signatures: Gathering Energy

Lesson Stats

- Average time spent: 1–2 hours

Learning Objectives

- See Instructor's Guide

Assessment

Max score: 75

Lesson Flow

- Introduction on Nutrients in Food, Screens 1-3
- Carbohydrates, Screens 4-8
- Cellular Respiration, Screens 9-12
- Trophisms and Different Sources of Energy, Screens 13-19
- Chemistry Review, Screens 20-28
- Electron Acceptors and Donors, Screens 29-30.
- ATP the Energy Storage Molecule, Screens 31-32
- Reflection and Summary, Screens 33-34

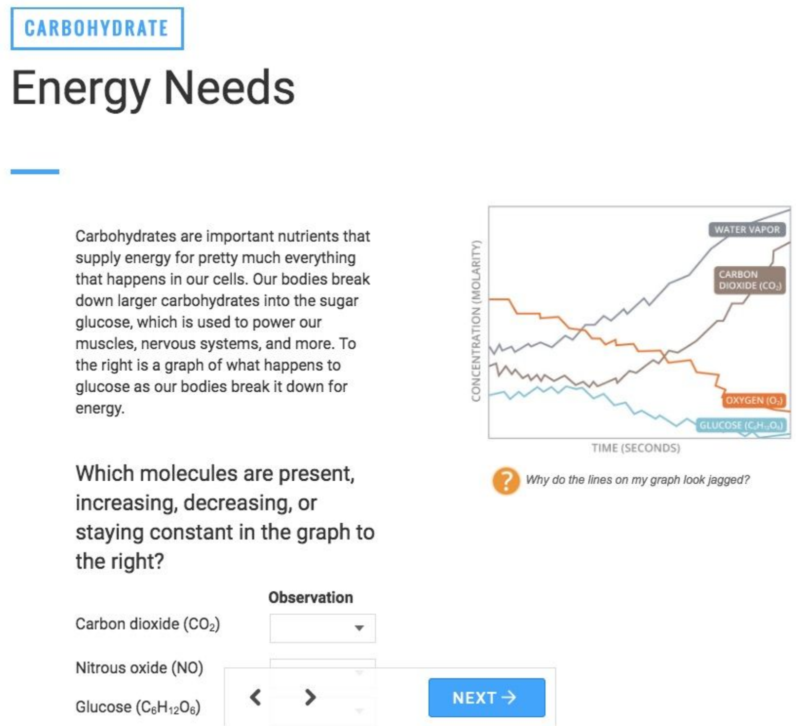
Common Student Issues/Misconceptions

- Another point of difficulty for students is reading and interpreting energy graphs. If students have difficulty with graphs they are provided the option to complete a quick graphing review.
- Students sometimes have trouble understanding the role electrons play in cellular respiration. “Keeping track” of where the electrons go in terms of energy acceptors and donors can be a challenge.

Simulations
N/A

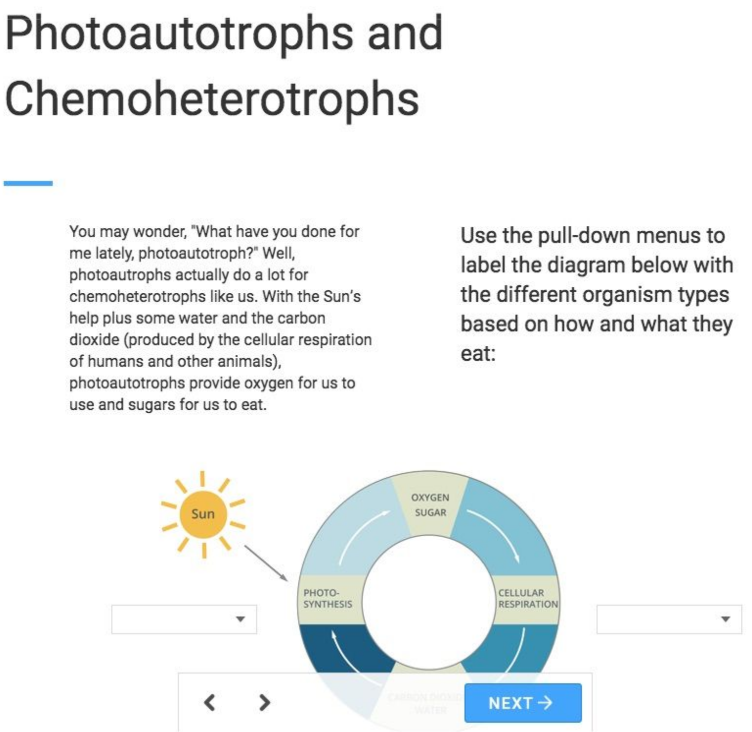
Activity Walk-through

1. Energy Needs (Screen 6)



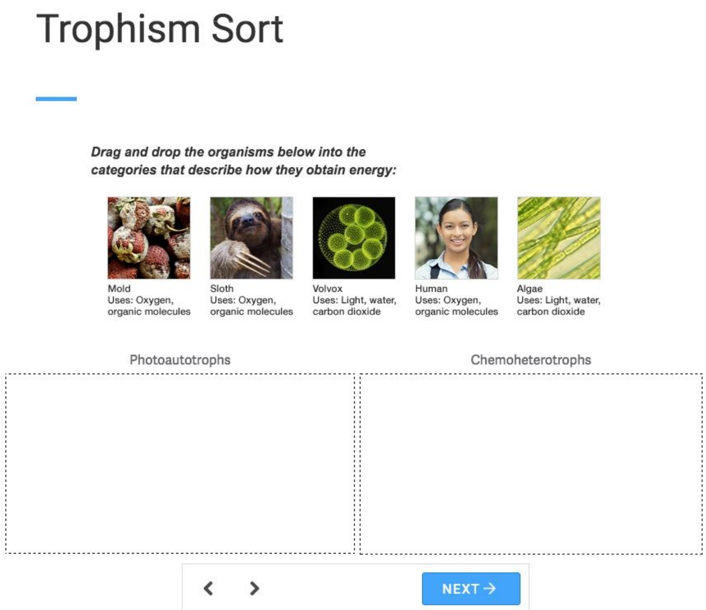
Here students practice reading a graph and consider what products are given off when carbohydrates are used up by the body. Students should pay attention to the inverse relationship between the glucose and carbon dioxide molecules.

2. The Relationship Between Heterotrophs and Photoautotrophs (Screen 17)



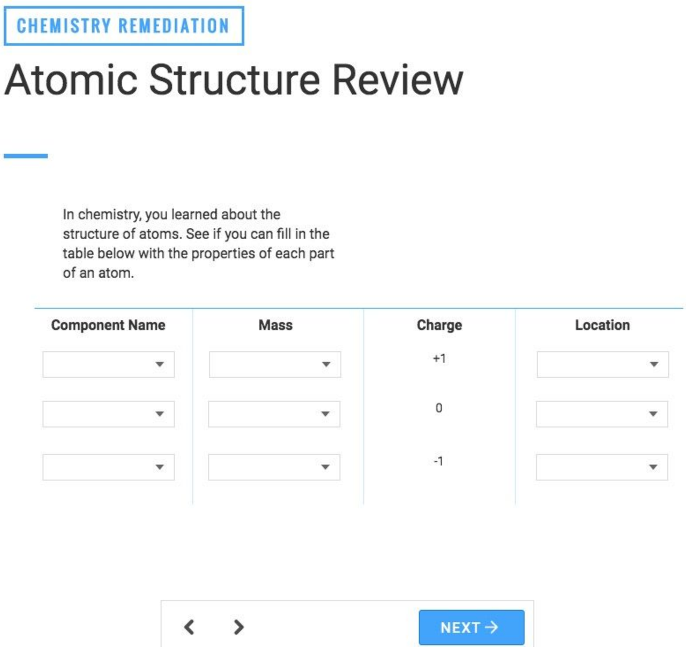
On this screen students will consider the relationship and differences between types of organisms. Students are to use the pull-down menu to label the diagram below with the different organism types based on how and what they eat.

3. Sorting Organisms into Different Trophisms



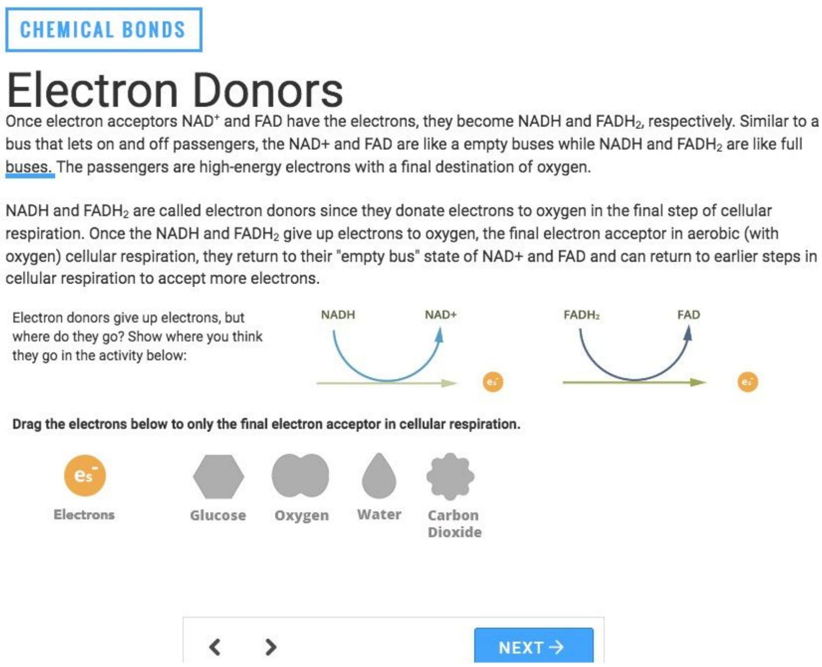
In this activity students will directly sort different organisms into the respective categories of photoautotrophs and chemoautotrophs based on the descriptions of each image.

4. Atomic Structure Review



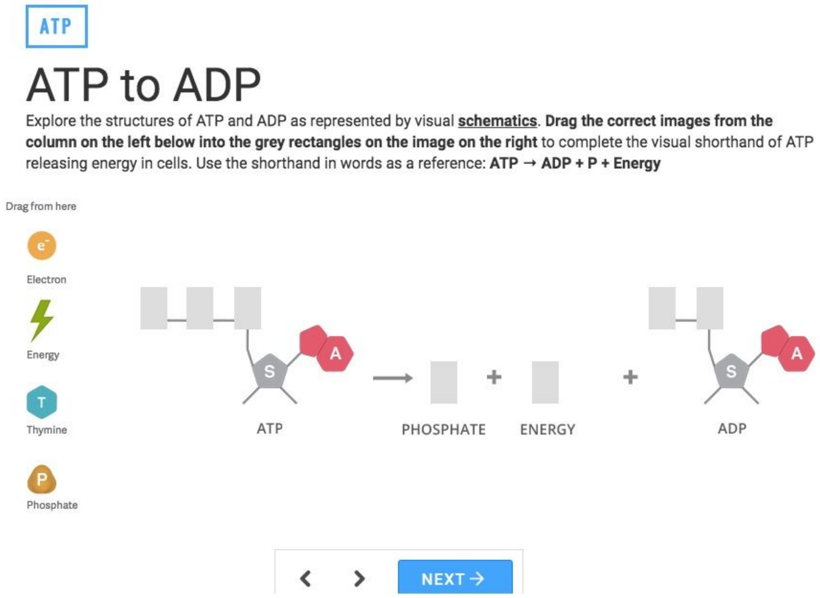
On this screen students will recall basic chemistry information that will prove crucial for their understanding of the rest of activities.

5. Electron Acceptors (Screens 29)



On this screen students will see the important role that charges play in facilitating chemical reactions and energy transfer. Students will become more familiar with the specific molecules involved in a number of metabolic processes that will be mentioned later on in the following lessons.

6. ATP to ADP in Schematic Form (Screen 32)



On this screen students will become more familiar with the critical energy molecule, ATP. Students will practice dragging and dropping the various monomers to build the molecules.

Unit 6 Searching for Signatures: Energy Challenge — Respiration

Lesson Stats

- Average time spent: 1.5–3 hours

Learning Objectives

- See Instructor's Guide

Assessment

Max score: 273

Lesson Flow

- Introduction, Screens 1-2
- Cellular Respiration Graphing, Screens 3-4
- Glycolysis, Screens 5-13
- Choose Your Path, Screen 14

- Fermentation, Screens 15-22
- Anaerobic Electron Transport, Screens 23-30
- Krebs Cycle, Screens 31-36
- Electron Transport Chain, Screens 37-43
- ATP Synthases, Screen 44
- Reflection and Summary, Screens 45-46

Common Student Issues/Misconceptions

- Students learning about cellular respiration for the first time sometimes have a hard time understanding which among the different energy generating pathways is necessary for the others to progress. The various simulations in this lesson help to illustrate how products of glycolysis are necessary for the Krebs Cycle and later the Electron Transport Chain.

Simulations

Simulation name: Glycolysis Energy Challenge

- Description: This simulation will take students through the steps of glycolysis by allowing them to drag and drop the molecular ingredients necessary to run the pathway.
- Correct answer: Students must drag and drop the correct molecules in order to activate glycolysis. Once they have done that and successfully generated enough ATP they can move on.

Simulation name: Fermentation + Glycolysis Energy Challenge

- Description: This simulation will take students through the steps of fermentation by allowing them to drag and drop the molecular ingredients necessary to run the pathway.
- Correct answer: Students must drag and drop the correct molecules in order to activate glycolysis and glycolysis without oxygen (fermentation). Once they have done that and successfully generated enough ATP they can move on.

Simulation name: Krebs Simulation

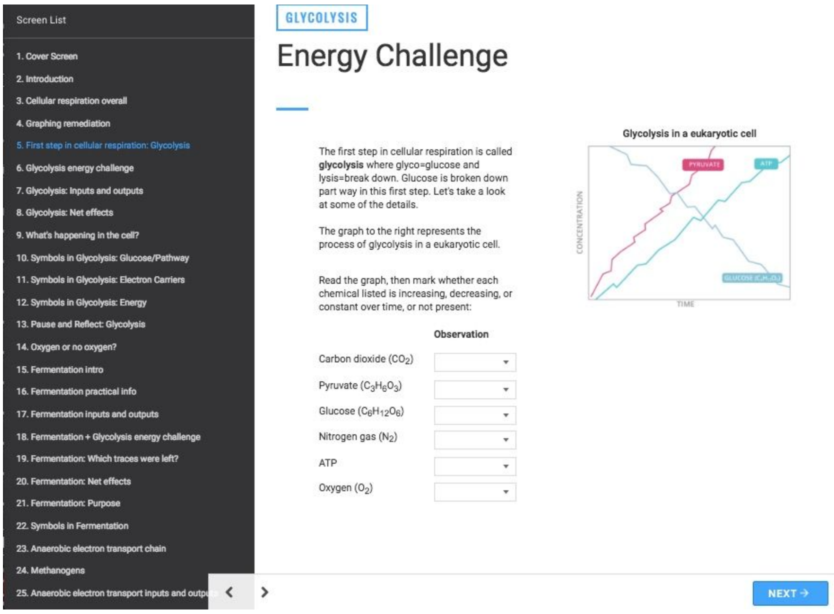
- Description: This simulation will take students through the steps of the krebs cycle by allowing them to drag and drop the molecular ingredients necessary to run the pathway.
- Correct answer: Students must drag and drop the correct molecules in order to activate glycolysis and the Krebs cycle. Once they have done that and successfully generated enough ATP they can move on.

Simulation name: Electron Transport Simulation

- Description: This simulation will take students through the steps of the electron transport chain by allowing them to drag and drop the molecular ingredients necessary to run the pathway.
- Correct answer: Students must drag and drop the correct molecules in order to activate glycolysis, the Krebs Cycle and the Electron Transport Chain. Once they have done that and successfully generated enough ATP they can move on.

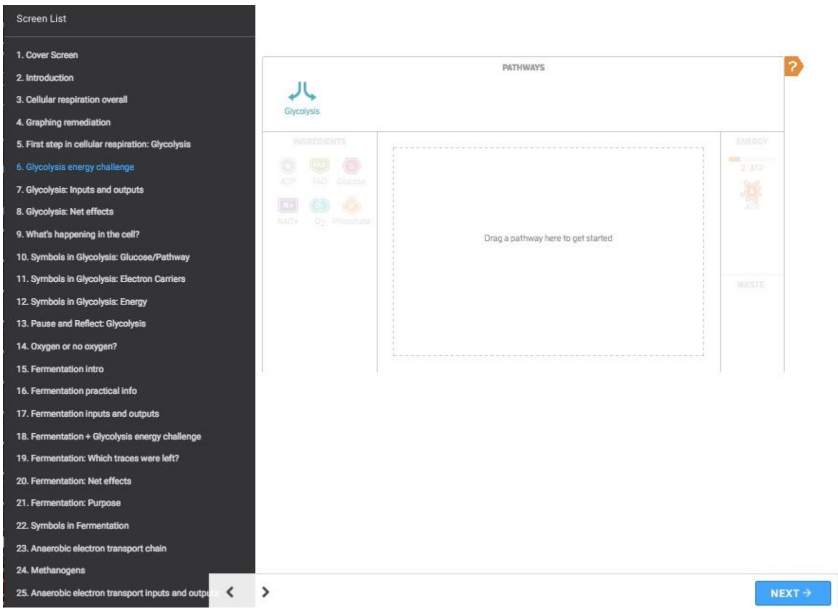
Activity Walk-through

1. Cellular Respiration Graphing Activity (Screen 3)



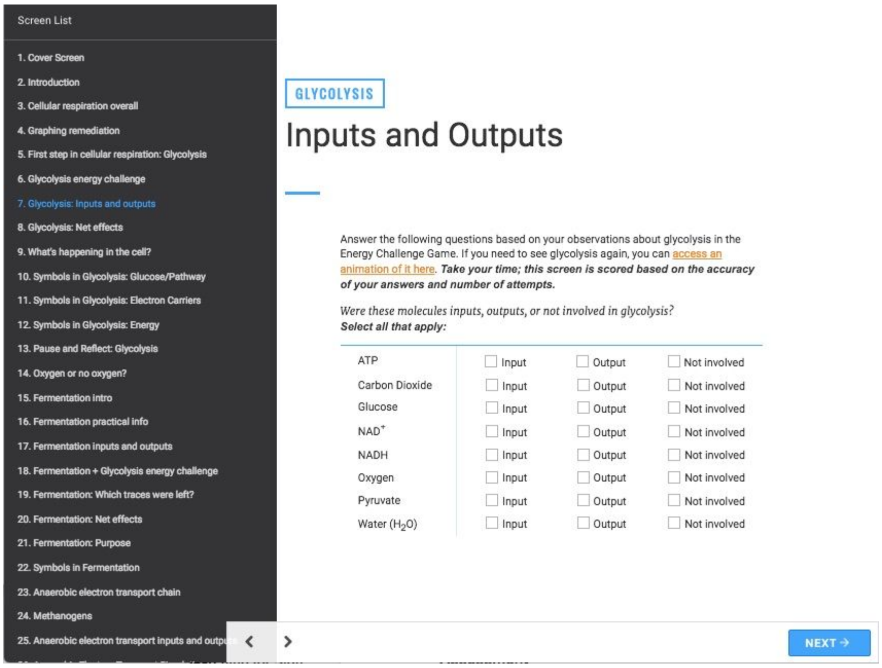
This screen is the first of several instances where students will practice reading and interpreting a graph to understand what inputs and outputs are involved in glycolysis and a variety of metabolic pathways.

2. Glycolysis Energy Challenge (Screen 6)



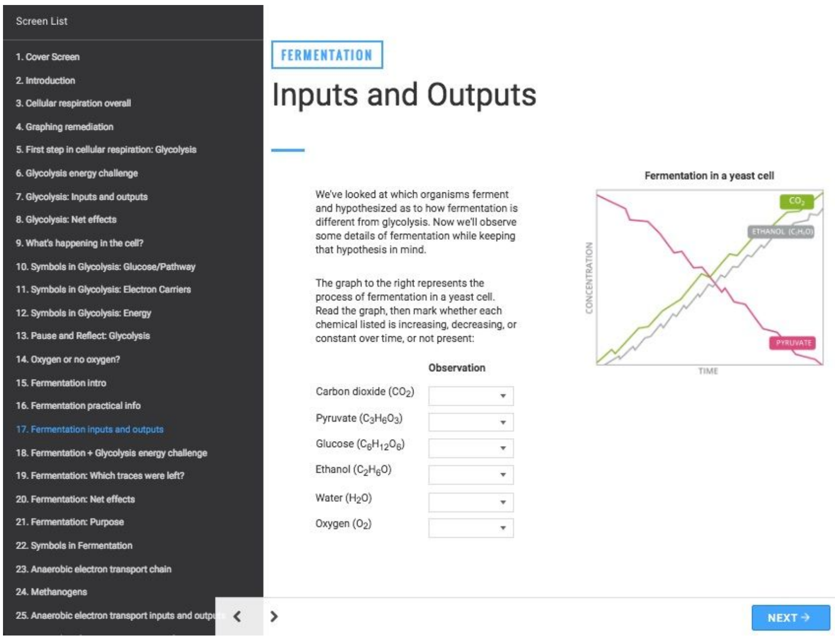
After reviewing the general things that happen in glycolysis from the graph on the previous screen students will use the simulation to visualize what products are needed to run glycolysis.

3. Net Effects of Glycolysis



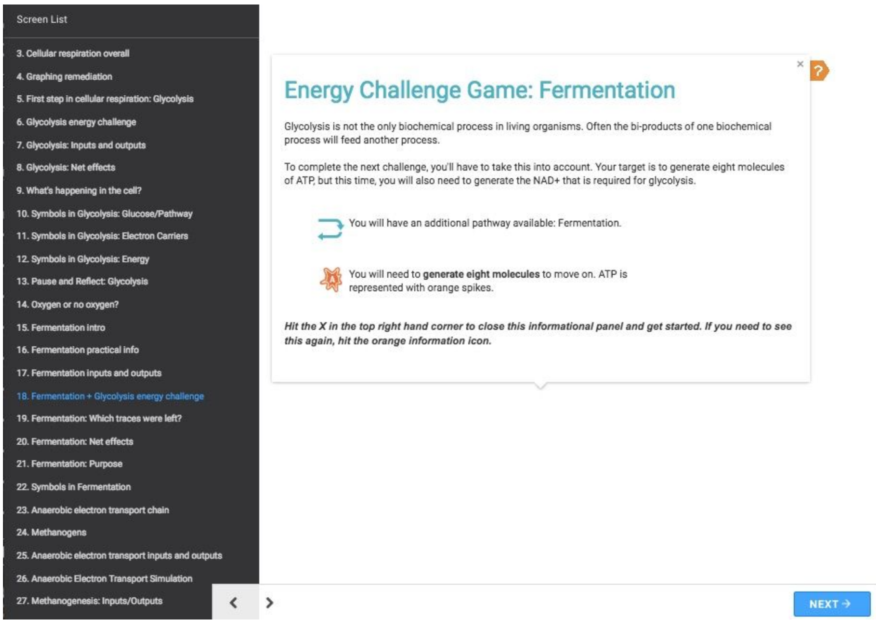
After the simulation students will recall the molecules that needed to run glycolysis.

4. Fermentation Graphing Activity



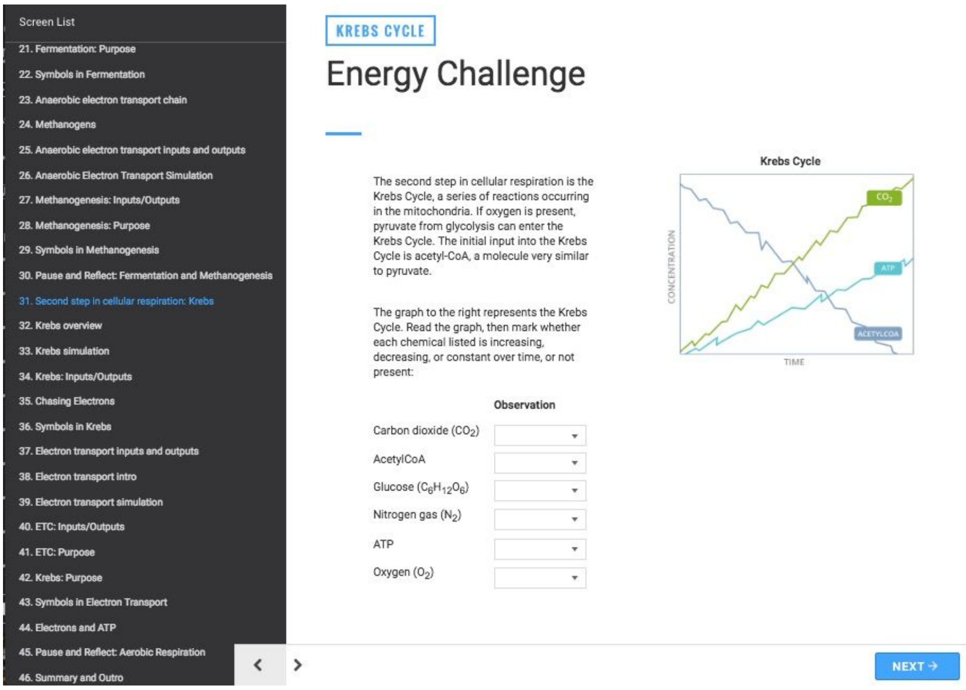
Just like in the glycolysis graphing activity, students will practice reading and interpreting the graph so that they can become familiar with the general trends happening within fermentation.

5. Simulation: Fermentation



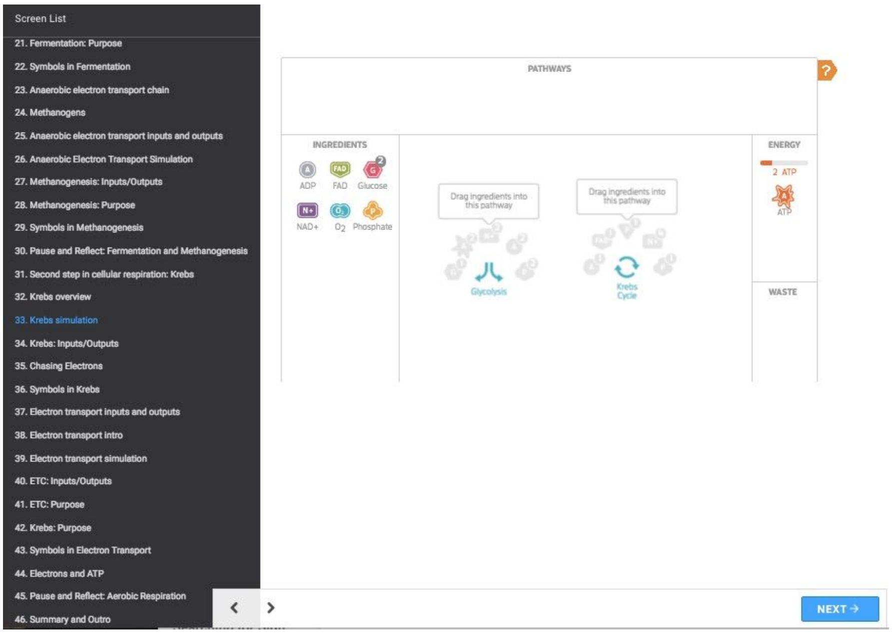
As in the previous simulation concerning glycolysis, students will use the simulation to visualize what products are needed to run fermentation.

6. Krebs Simulation



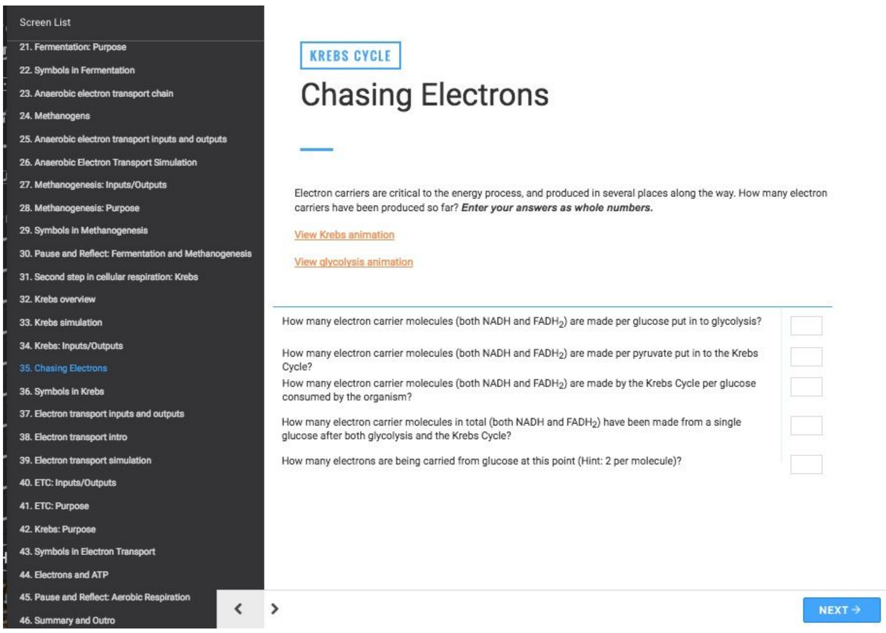
As on the previous screens students will read and interpret this graph to understand what are the inputs and outputs of the Krebs Cycle. This will prepare them for the subsequent simulation.

7. Krebs Cycle Simulation



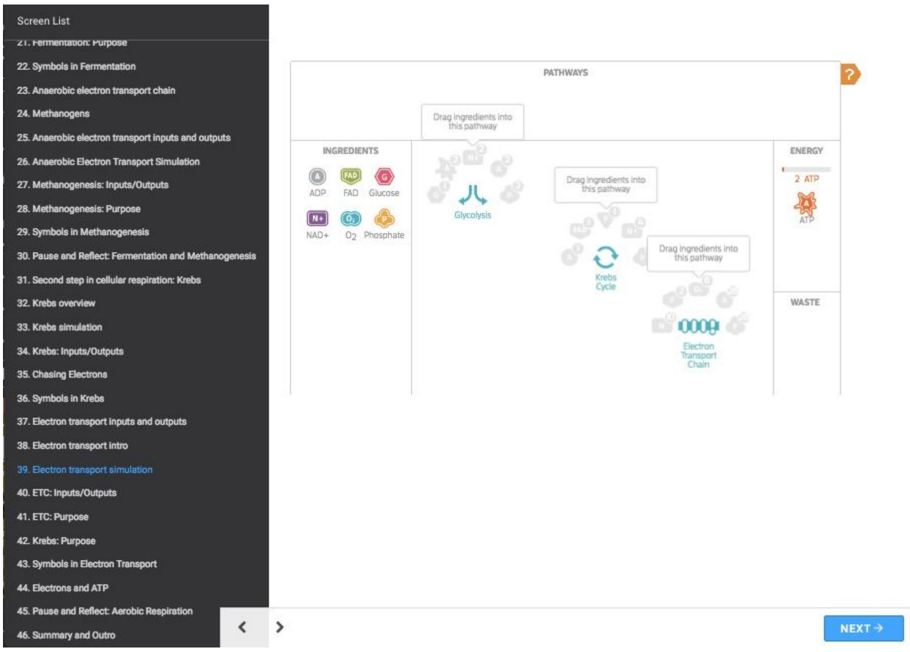
Building upon the Glycolysis and Krebs simulation activities, students will combine them to see how the two are related.

8. Krebs Cycle Taken Further

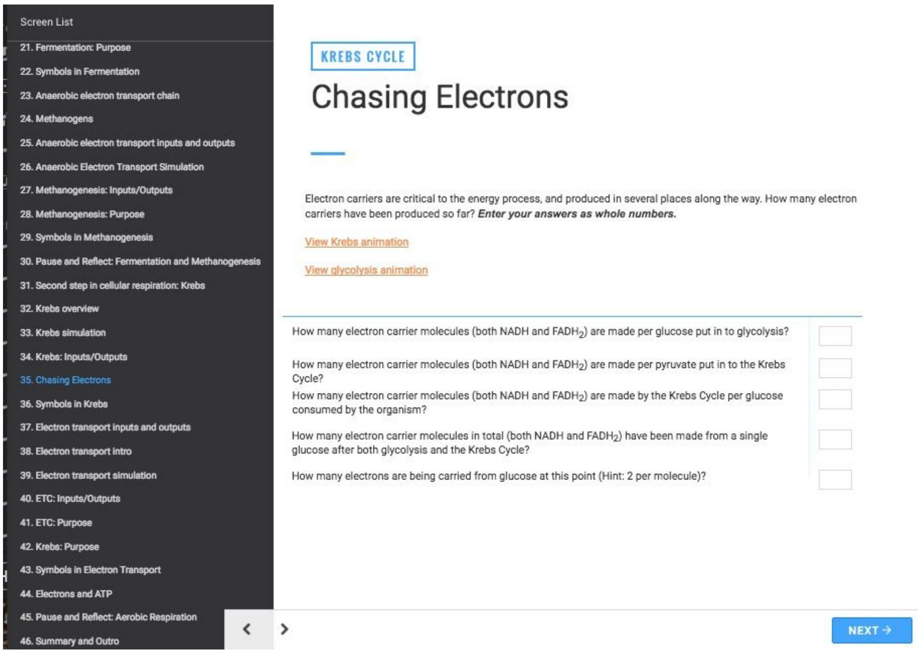


This slide encourages students to consider how electrons play a role in the previous explored energy pathways. This slide will introduce students to the concept of the Electron Transport Chain in the subsequent slides.

9. Simulation: Electron Transport Chain



This is the most comprehensive simulation in the the Cellular Respiration lesson. Students will actively combine glycolysis, the krebs cycle and the electron transport chain to see how all three play into aerobic respiration and energy generation. If the students do the steps out of order they will soon see that they cannot generate energy as efficiently if they were to follow the steps in order.



Like in the krebs cycle simulation, students will track the whereabouts of the electrons in this electron transport chain.

Unit 6 Searching for Signatures: Energy Challenge — Photosynthesis

Lesson Stats

- Average time spent: 1.5-3 hours

Learning Objectives

- See Instructor's Guide

Assessment

Max score: 211

Lesson Flow

- Introduction, Screens 1-2
- What is Light?, Screens 3-10
- Photosynthesis Challenge Reflection, 11-12
- Photosynthesis Overview Graphing, Screens 13-15
- Light Dependent Reactions, Screens 16-18
- Light Dependent Reactions Simulation, Screen 19
- Components of Light Dependent Reactions, Screens 20-22

- Light-independent Reactions and Calvin Cycle, Screens 23-24
- Calvin Cycle Reaction Simulation, Screen 25
- Calvin Cycle, Screens 26-27
- Anoxygenic Photosynthesis, Screens 28-32
- Pause and Reflect, Screen 33
- Photosynthesis Review and Glucose Combustion, Screens 34-35
- Summary and Outro, Screen 36

Common Student Issues/Misconceptions

- One common student misconception is that plants obtain their carbon biomass from the soil. This however is incorrect because they get it from sequestering carbon dioxide in the atmosphere with the help of energy from the sun.
- Another common misconception is that the light-independent reactions, sometimes called “dark reactions”, occur only when there is no sun. On the contrary they actually can occur simultaneously with the light-dependent reactions, they just don’t require the light of the sun.

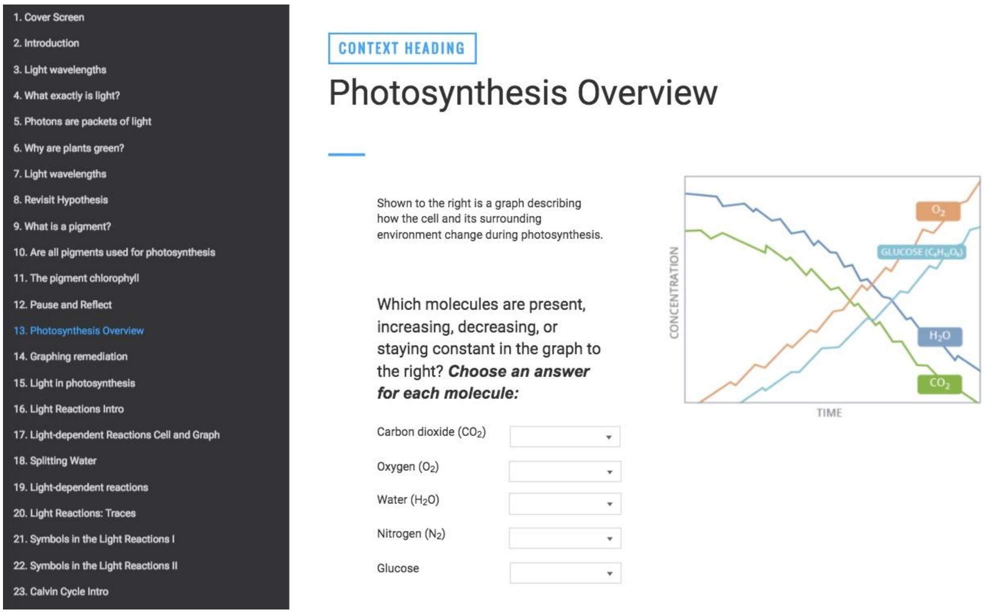
Simulations

Simulation name: Energy Challenge Simulation

- Description: This simulation is comprised of three different parts that take students through different pathways involved in photosynthesis. In the first part of the simulation students are taken through the light-dependent reaction. The next part of the simulation covers the light-independent reaction which takes students through the light-independent reaction (Calvin Cycle) by allowing them to drag and drop the molecular ingredients necessary to run the pathway. Students will notice that the energy created in the light-dependent reaction will be used in this part to help build the glucose molecule. The last part of the energy challenge simulation covers anoxygenic photosynthesis. Just as students did in the previous part of the simulation they are to drag and drop the molecular ingredients necessary to run the pathway. Students will notice that water is not needed as an electron donor for the light-dependent reaction.
- Correct Answer: Students must drag and drop the correct molecules in order to activate the light-dependent, the light-independent, and anoxygenic reaction pathways. Once they have done that and successfully generated enough glucose, ATP and NADPH they can move on.

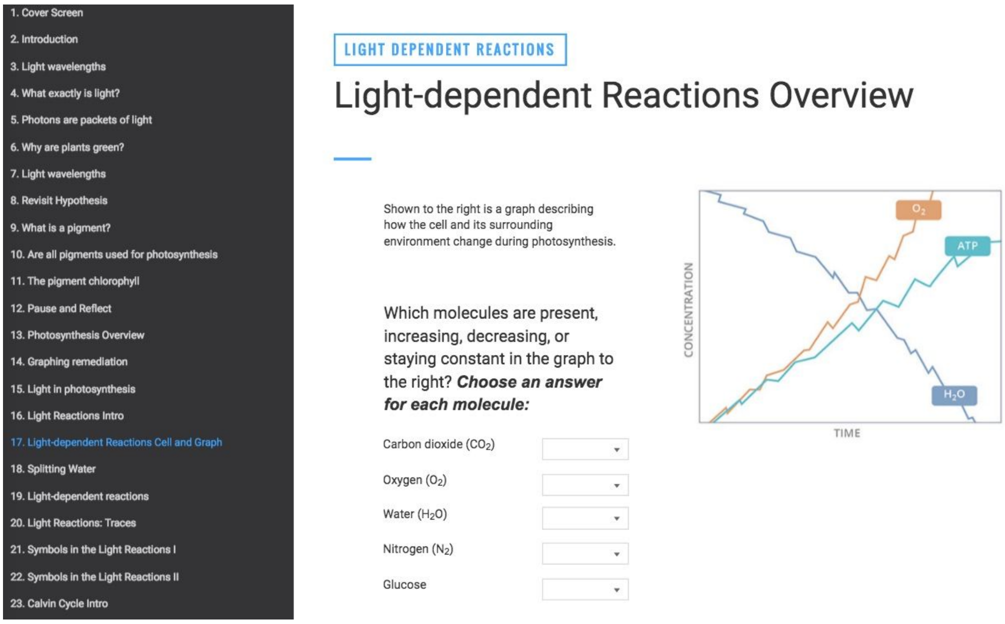
Activity Walk-through

1. Photosynthesis Overview and Graph Interpretation (Slide 13)



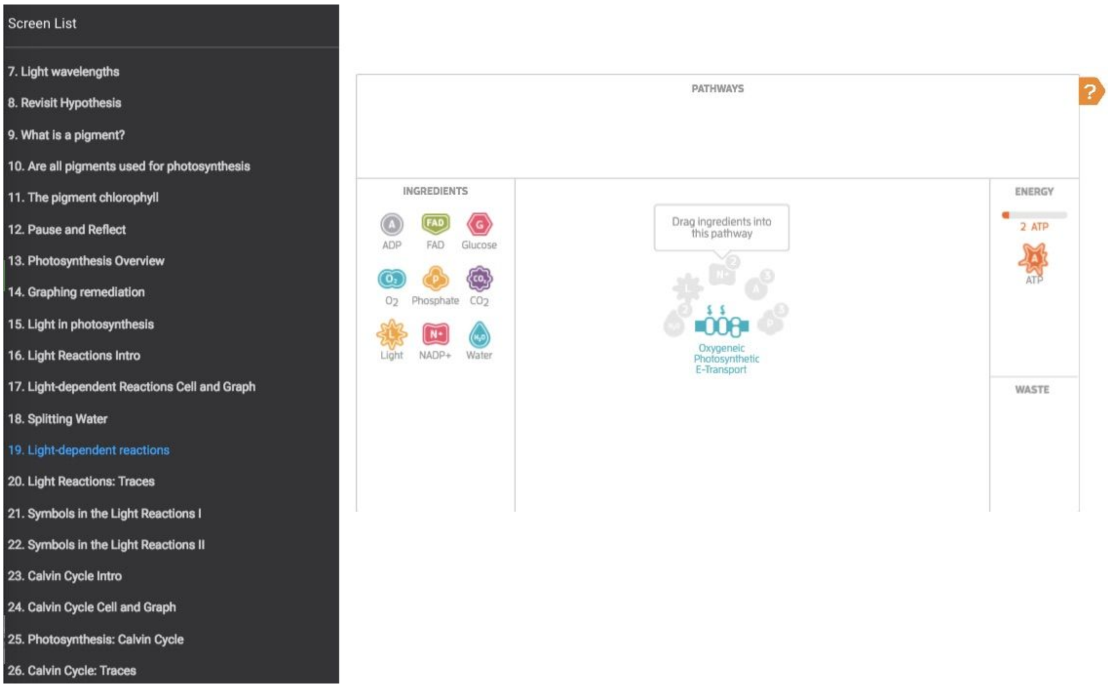
This screen is the first of several instances where students will practice reading and interpreting a graph to understand what inputs and outputs are generally involved in photosynthesis.

2. Light-dependent Reaction Overview and Graph Interpretation (Screen 17)



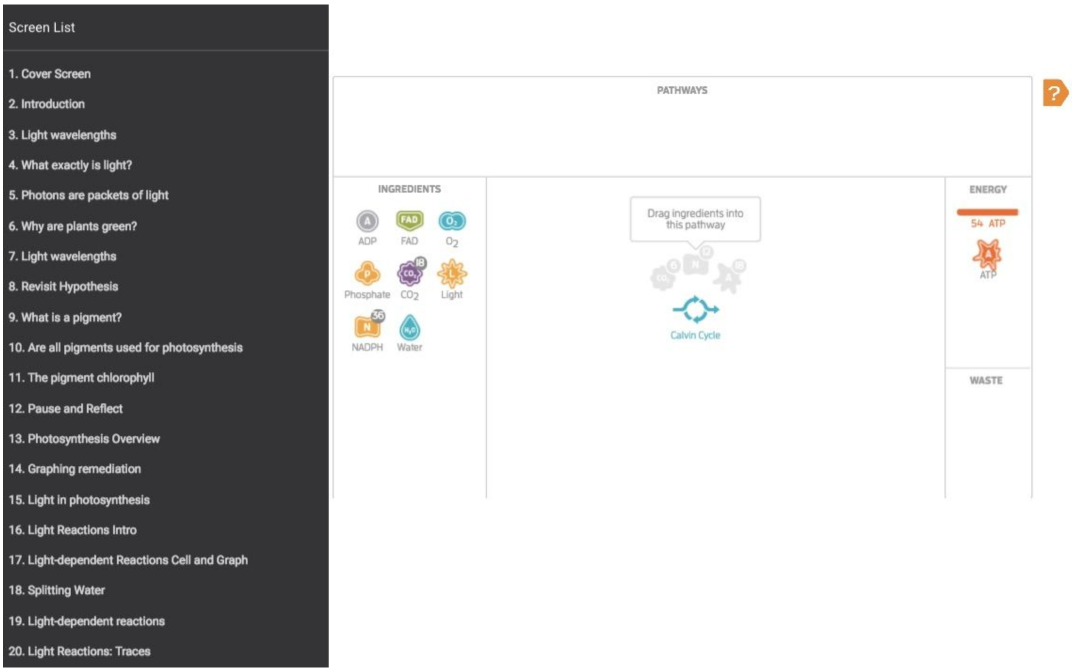
On this screen students will read and interpret a graph covering the light-dependent reactions in preparation for the simulation on the next screen.

3. Light-dependent Reaction Simulation (Screen 19)



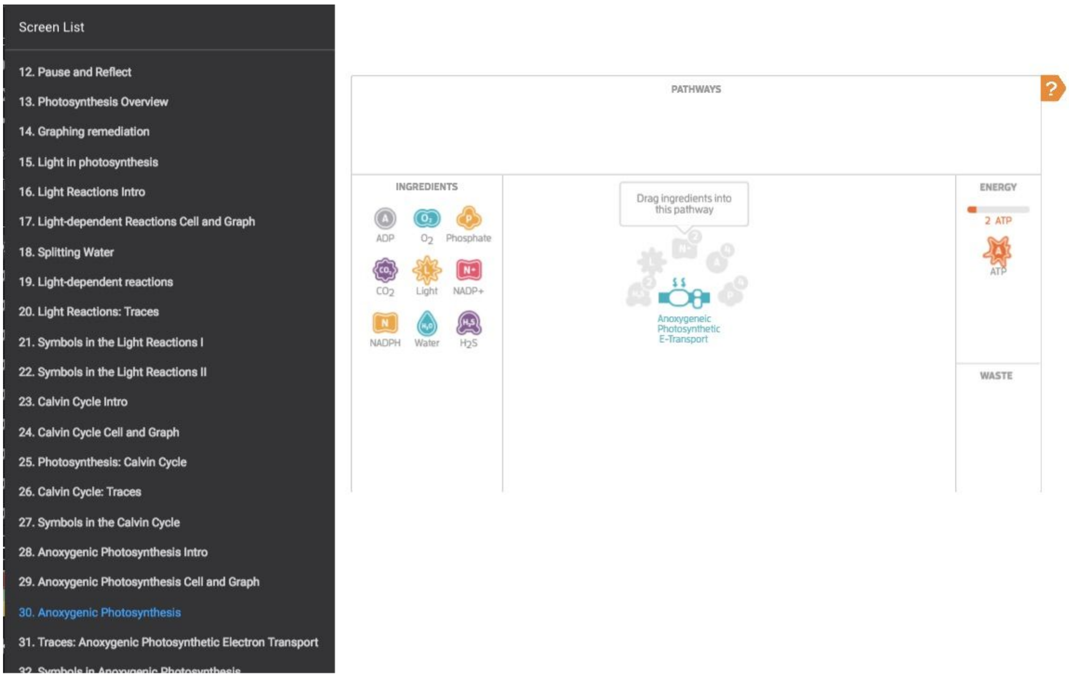
This screen will introduce students to the their first simulation in this lesson. Here students will drag and drop “ingredients” such as ADP, ATP, FAD, Glucose, Oxygen, Phosphate, Carbon Dioxide, Light, NADP+ and water into the oxygenic photosynthetic E-Transport pathway.

4. Light-independent Reaction Calvin Cycle Simulation (Screen 25)



This screen will introduce students to the their first simulation in this lesson. Here students will drag and drop “ingredients” such as ADP, ATP, FAD, Oxygen, Phosphate, Carbon Dioxide, Light, NADPH, and water to the Calvin Cycle pathway in order to produce some glucose molecules.

5. Anoxygenic Photosynthesis (Screen 30)



This screen will introduce students to the their first simulation in this lesson. Here students will drag and drop "ingredients" such as ADP, ATP, FAD, Oxygen, Phosphate, Carbon Dioxide, Light, NADPH, and water to the anoxygenic photosynthesis pathway. This pathway does not require water and students with students will notice when adding "ingredients".

Unit 6 Searching for Signatures: Genetic Blueprints

Lesson Stats
- Average time spent: 1-2 hours

Learning Objectives
- See Instructor's Guide

Assessment
Max score: 177

Lesson Flow
- Introduction, Screens 1-2.
- Gregor Mendel, Screen 4.
- Griffith's Experiments, Screens 5-8.
- Hershey-Chase Experiments, Screens 9-19.
- DNA Structure, Screens 20-23.
- Building nucleotides, Screens 24-27.
- Photo 51 and double stranded DNA, Screens 28-30.
- Building double stranded DNA, Screens 31-35.
- Explore DNA, Screen 36.
- RNA, Screen 37.
- TNA, Screen 38.

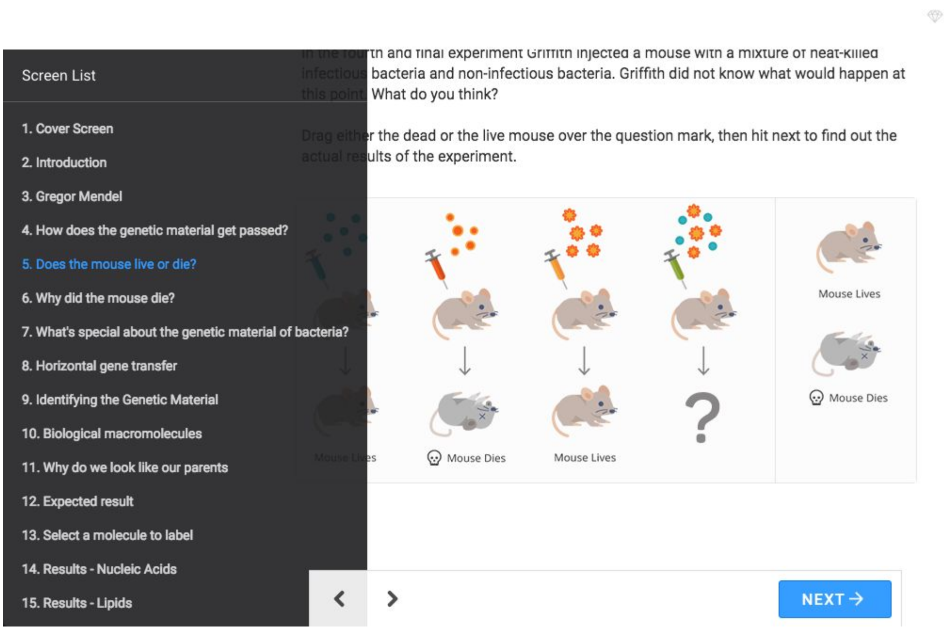
- Summary, Screen 40.

Common Student Issues/Misconceptions

- Most student difficulties during this lesson are with the widgets and building nucleotides/DNA strands. On Screen 25, students will be asked to build a strand that is 10 nucleotides long. The screen will only show about 5-7 nucleotides. In order to add more to the strand, students will have to physically move the strand, on the screen, up or down in order to increase the length.
- Students can also find difficulty with the base pairing simulation due to its immersive nature. Students begin without being provided rules for how to run the simulation but are instead encouraged to explore and play around with matching base pairs without being being told the answer out right.

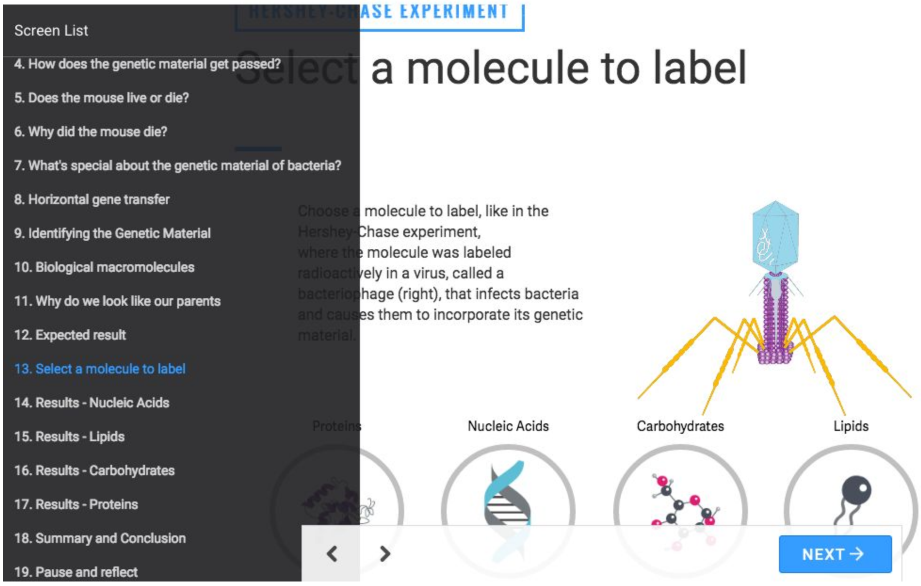
Activity Walk-through

1) Does the mouse live or die? (Screen 5)



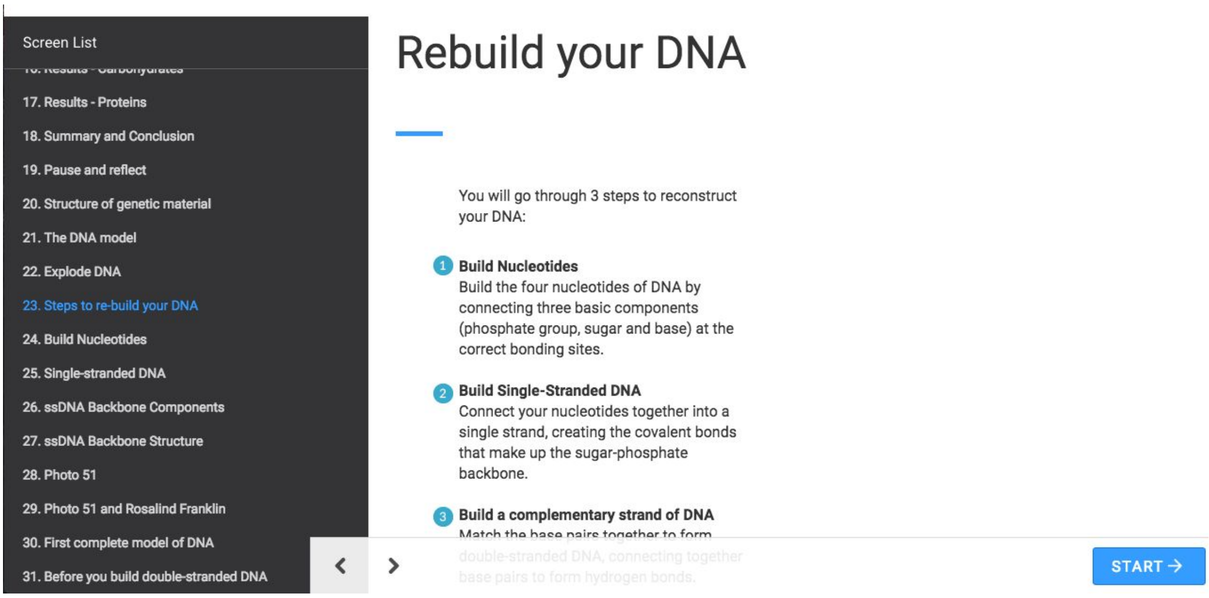
Students need to understand the basis of Griffith's experiment and be able to determine the outcome of various scenarios, when asked. This screen helps them tie together what they have learned about this experiment and what the end result would be.

2) Select a molecule to label (Screen 13)



This screen and the subsequent screens will guide students through the Hershey-Chase experiment and help them discern which molecule is the genetic material. Students will go through the same methodology and thinking that was used in order to determine that nucleic acids made up genetic material.

3) Steps to re-build your DNA (Screen 23)

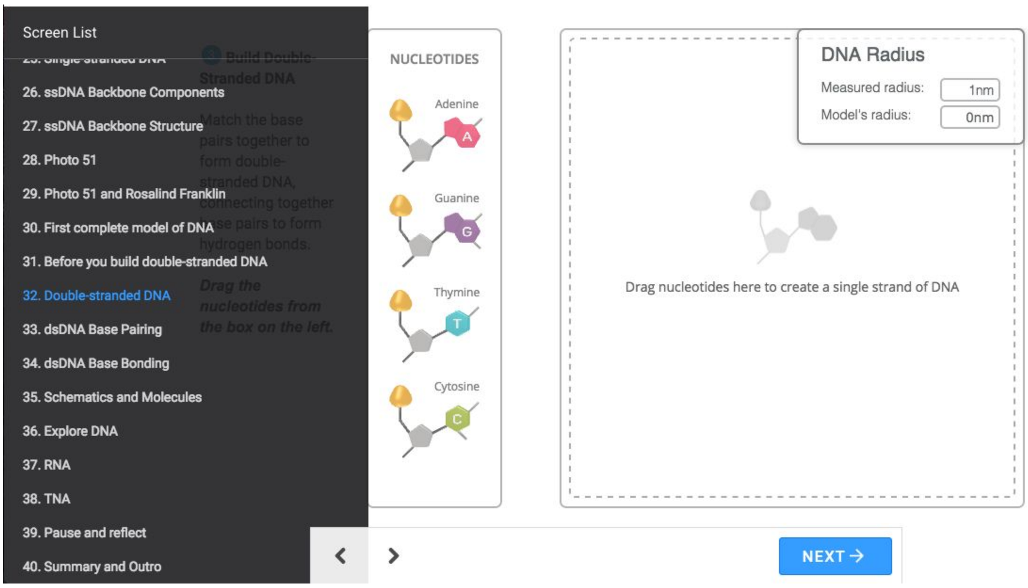


This screen explains how nucleotides will be built in the next couple of screens. Students need to read these instructions thoroughly to understand what they must do. Many students have a lot of trouble with these next screens as they get confused and do not understand what they are supposed to do. Refer them to this screen and the instruction on this screen if students are struggling.

4) Single-stranded DNA (Screen 25)

Students will be asked to build a strand that is 10 nucleotides long. The screen will only show about 5-7 nucleotides. In order to add more to the strand, students will have to physically move the strand, on the screen, up or down in order to increase the length.

5) Double-stranded DNA (Screen 32)



Students will be asked to build a single strand of DNA complementary to the previous strand that they had already built. This is the same process as when they were asked to build the nucleotide strand.

Unit 6 Searching for Signatures: Cellular Replication

Lesson Stats

- Average time spent: 1.5 hours

Learning Objectives

- See Instructor's Guide

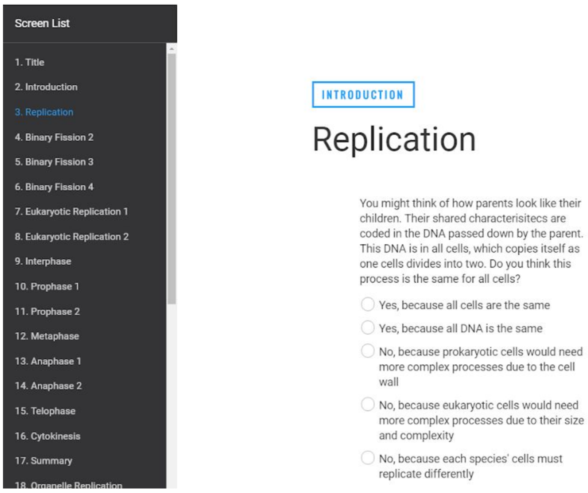
Assessment
Max score: 181

Lesson Flow
- Introduction, Screens 1-2.
- Replication and binary fission, Screens 3-6.
- Eukaryotic replication, Screens 7-8.
- Replication (Mitosis: Interphase → Cytokinesis), Screens 9-17.
- Endosymbiosis, Screens 20-22.
- Mitosis review, Screens 23-26.
- Meiosis overview, Screens 28-31.
- Meiosis: Meiosis I 1 → Meiosis II 4, Screens 32-38.
- Cell review, Screens 39-40.
- Summary, Screen 41.

Common Student Issues/Misconceptions
- Students should be able to differentiate between Mitosis and Meiosis and the stages for each. Many misconceptions arise because of the similarities between both.

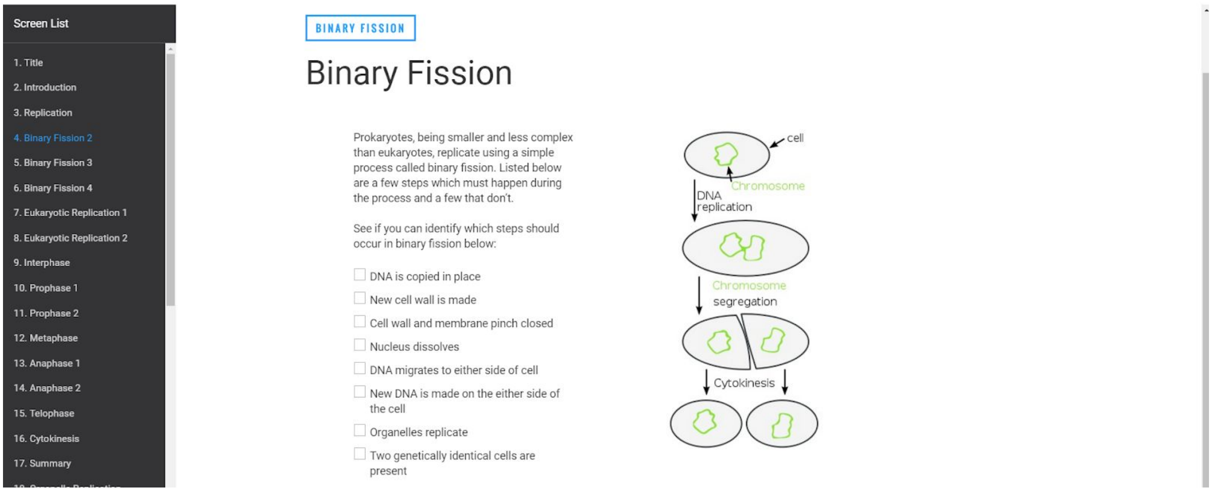
Activity Walk-through

1) Replication (Screen 3)



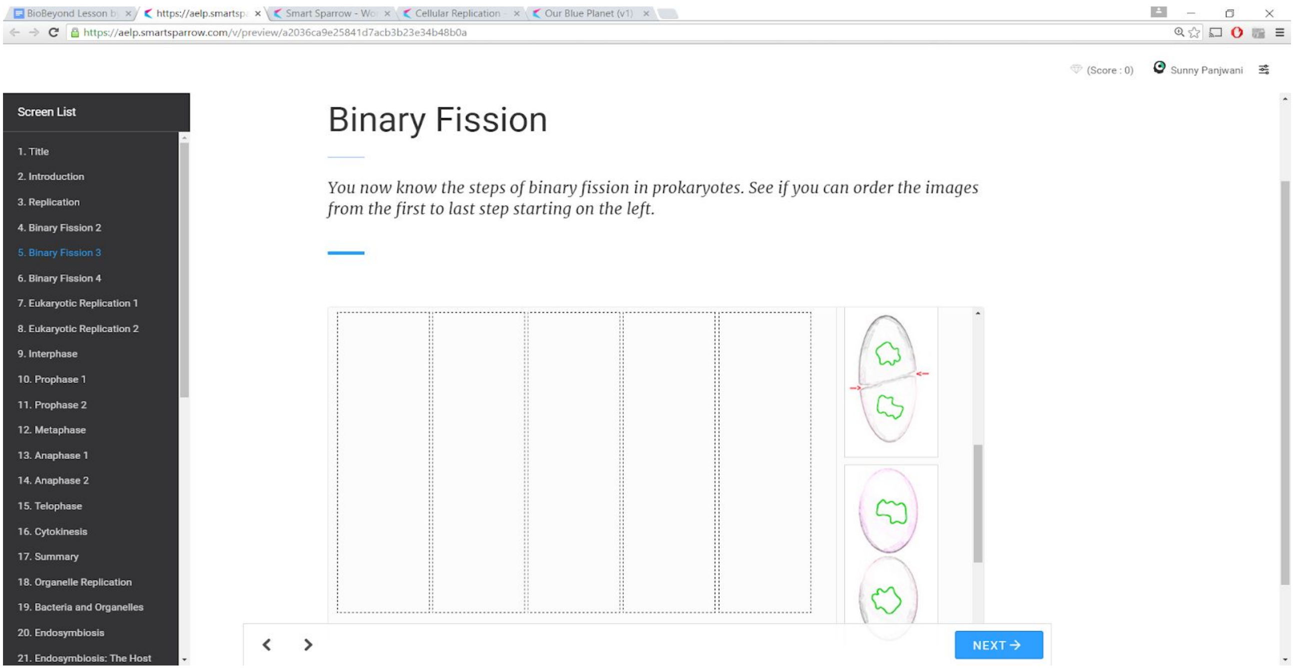
Students will be expected to utilize prior knowledge of DNA from previous lessons and apply them here to answer questions about the universality of replication.

2) Binary Fission (Screens 4-6)



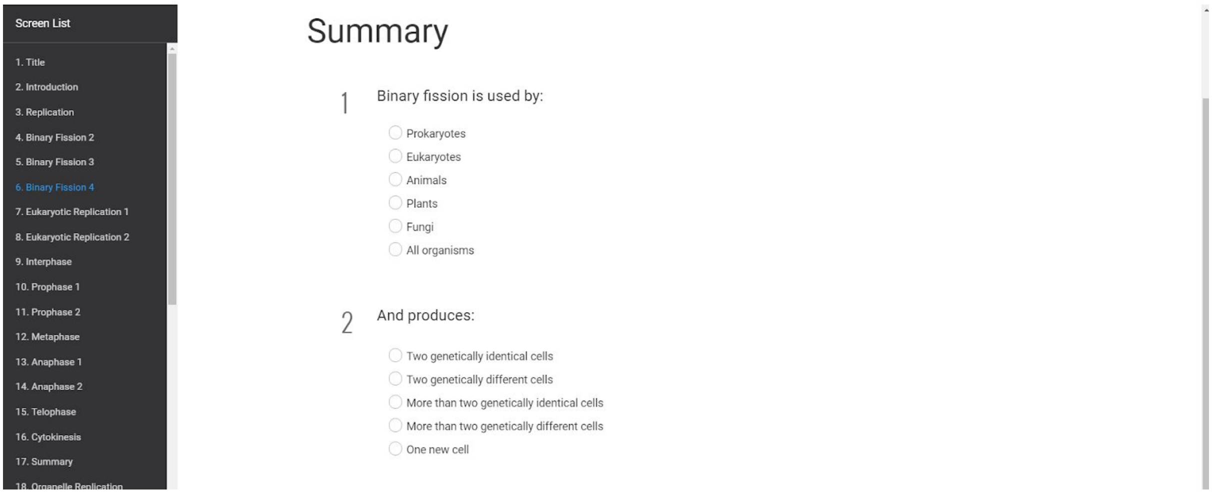
Students are asked to identify the correct steps involved in Binary Fission for simple prokaryotic organisms by using the image as a guide.

(Screen 5)



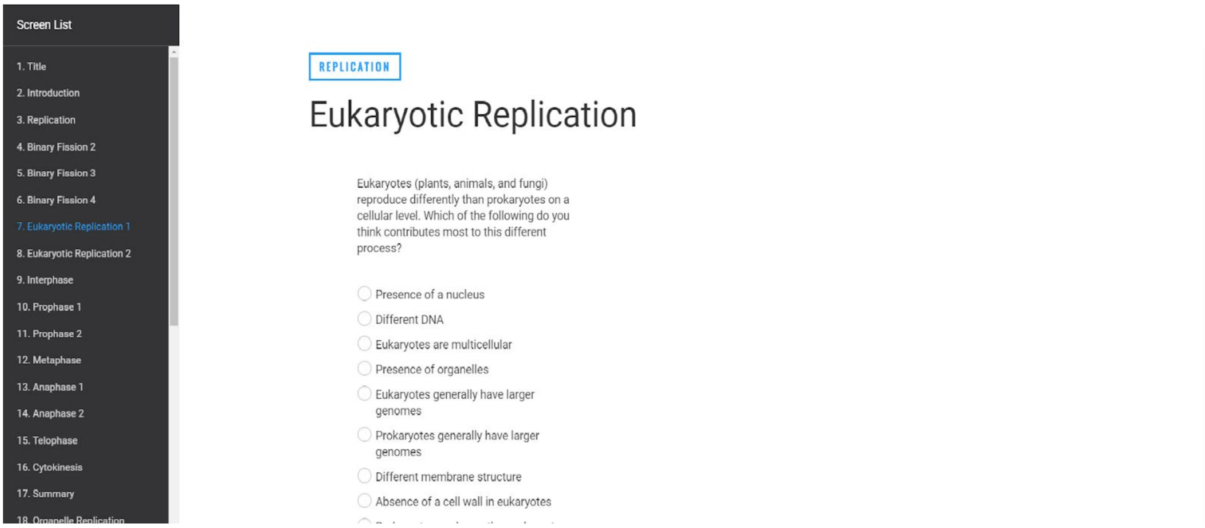
After selecting the correct steps of Binary Fission, students are tasked with correctly ordering the steps from the previous screen.

(Screen 7)



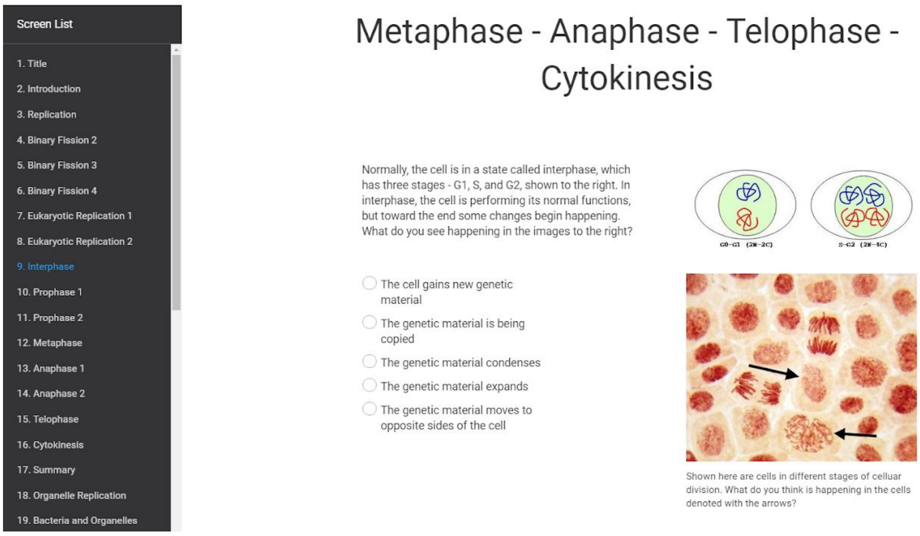
This screen concludes the Binary Fission instruction and leads into Eukaryotic Replication processes.

3) Eukaryotic Replication (Screens 7-8)

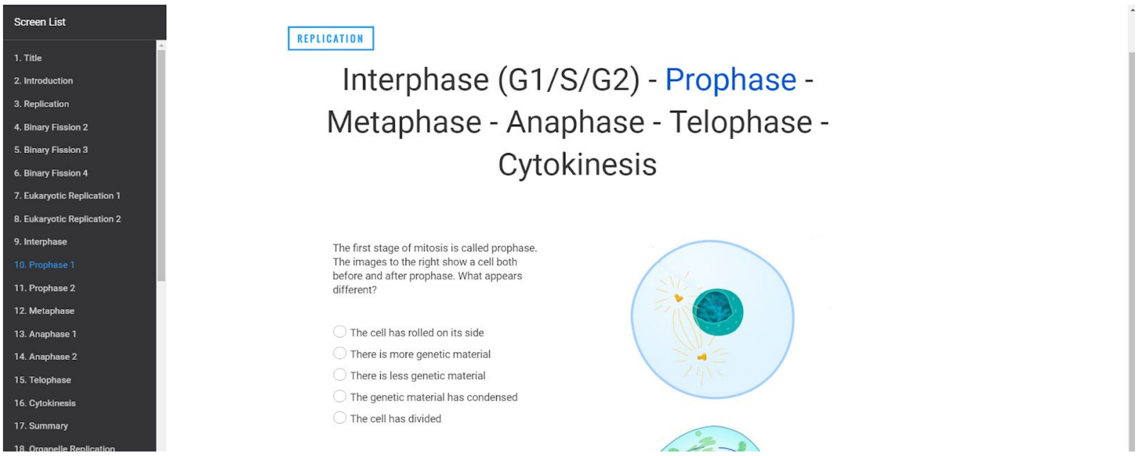


Eukaryotic Replication begins by introducing students to the idea of differentiated replication between eukaryotes and prokaryotes and probing at possible reasons for why. Students then proceed to view a short clip on the next screen as a precursor to learning the various stages of mitosis.

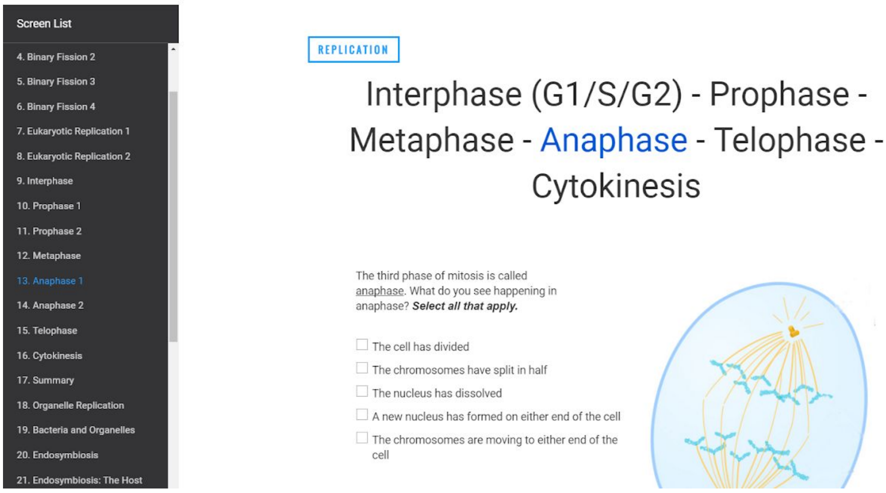
4) Replication (Mitosis: Interphase → Cytokinesis), Screens 9-17



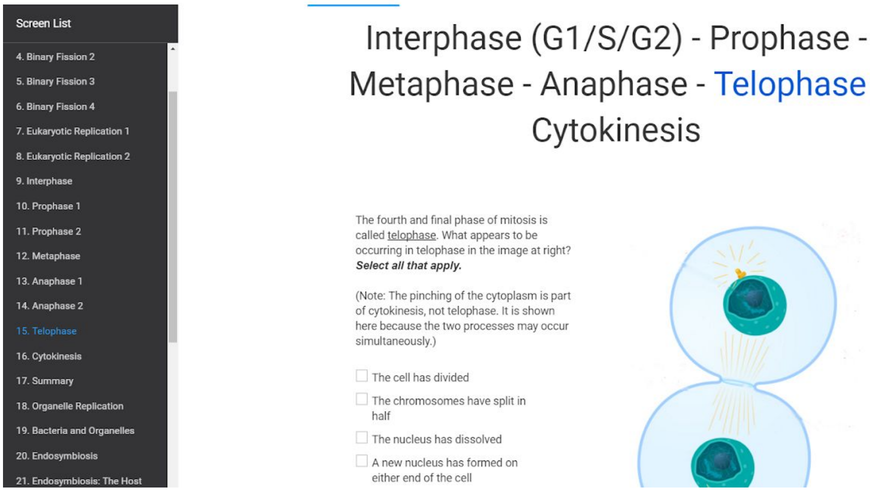
Students are introduced to the mitotic cycle by comparing cells in Interphase to those in various other stages of mitosis.



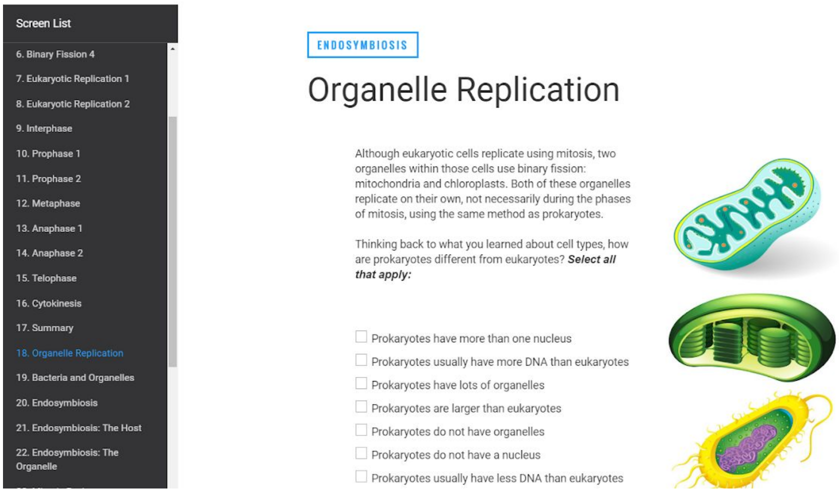
Screens 10-11 cover the first stage of the replication cycle, Prophase. Students are asked a variety of questions in order to create an initial understanding of cell behavior during replication.



Screens 13-14 introduce Anaphase, and require the student to answer questions related to the provided models of Anaphase.

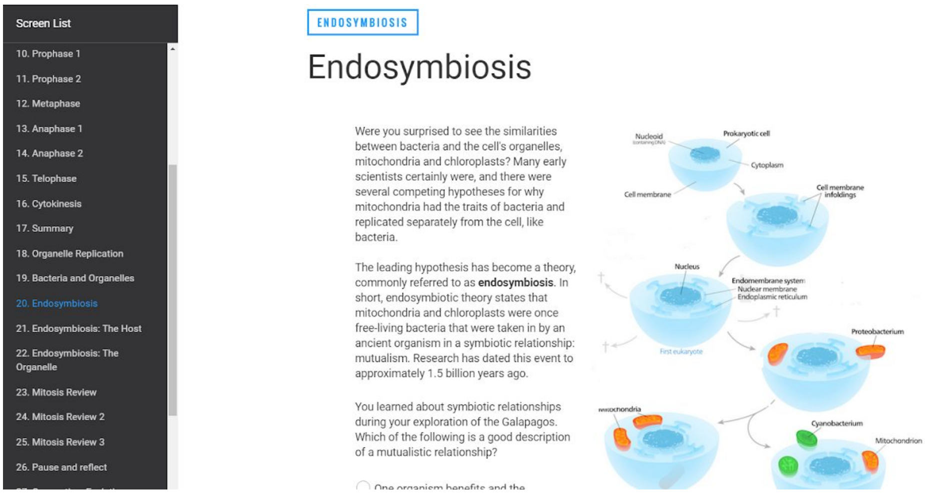


Screens 15-17 discuss Telophase, Cytokinesis, and conclude the mitotic instruction of this unit. Students are asked summary questions in order to solidify the basic mechanics of cell replication, as the following slides delve into the more detailed areas of replication.



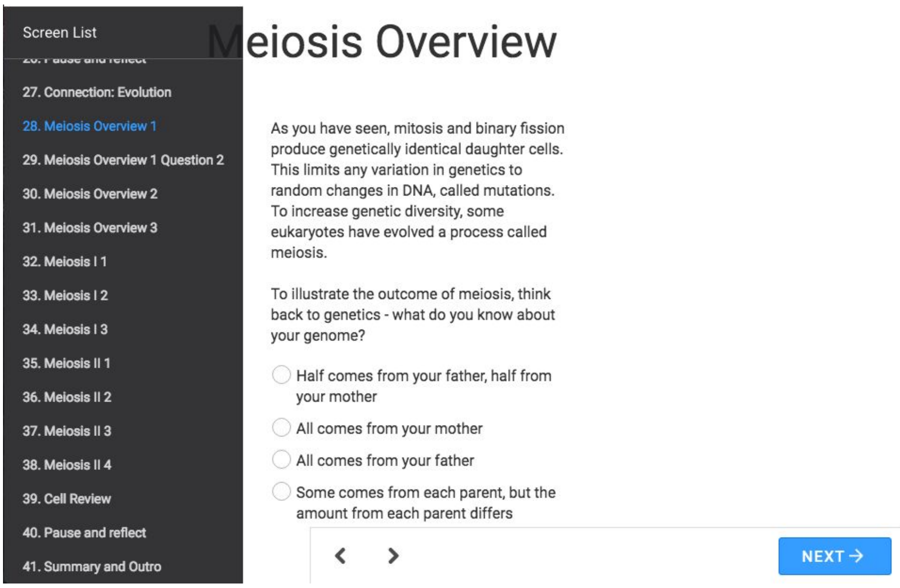
(Screens 18-19) allow the student to recap some of the major differences and similarities between single-celled and multicelled organisms, as the unit moves into the introduction of organelle replication and endosymbiosis.

5) Endosymbiosis, Screens 20-22



Screens 20-22 explore the concept of endosymbiosis, starting with some basic observations and concluding with more challenging concepts which require the student to think critically about the mechanics in play.

6) Meiosis overview (Screen 28)



Students will begin their journey through the stages of Meiosis starting with this screen. It is important that they understand the differences between each stage along with the differences between mitosis and meiosis.

Unit 6 Searching for Signatures: Replication

Lesson Stats

- Average time spent: 1.5 hours

Learning Objectives

- See Instructor's Guide

Assessment

Max score: 226

Lesson Flow

- Introduction, Screens 1-2.
- DNA Base Pairing, Screens 3-4
- Chromosomes, Screens 5-8.
- Gene mapping, Screens 9-10.
- Different chromosomes/chromatin, Screens 11-14.
- Unwinding DNA, Screens 15-16.
- Replication Race, Screens 17-18.
- 100 Base Challenge, Screen 19.
- Accuracy Challenge, Screen 20.
- Meselson and Stahl, Screens 21-25.
- Origin of Replication, Screen 26.
- Making new DNA, Screen 27.
- Okazaki Fragments, Screens 28-30.
- 100 Base Race, Screen 32.

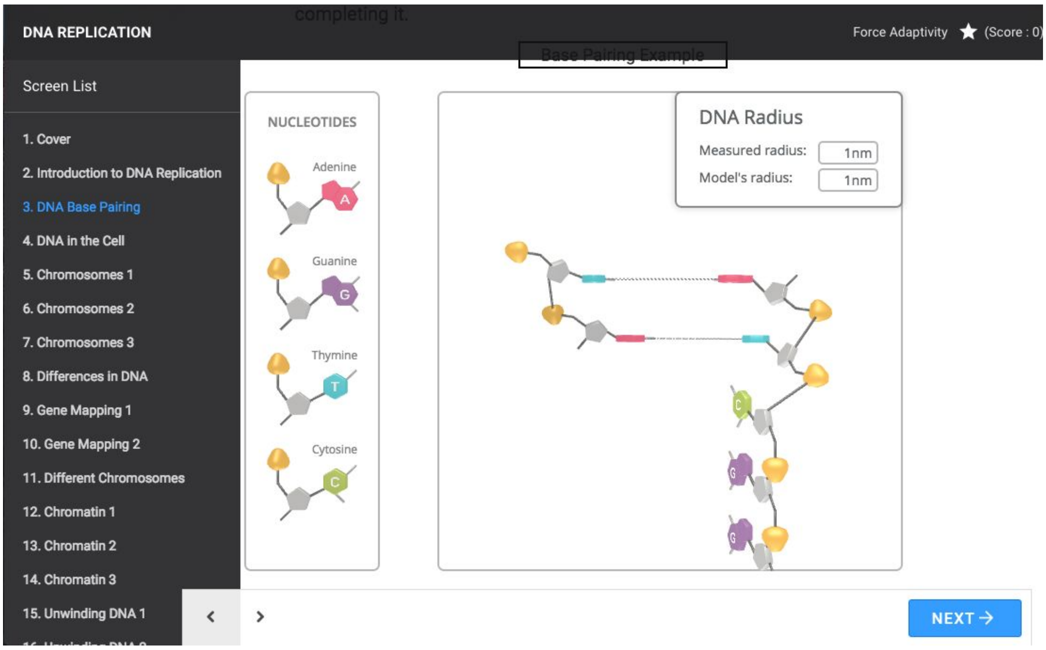
- Accuracy Race, Screens 34-35.
- Speed of replication, Screens 36-40.
- Replication in Cells, Screens 41-43.
- Stages of Replication, Screens 44-45.
- Summary, Screen 46.

Common Student Issues/Misconceptions

- Students will have to create a complementary strand and pair bases together. They are provided a template with one strand of bases and they have to match those bases by adding on their pair. As students keep adding on a pair, the double stranded strands grow. As before, students will have to keep pulling the strand up so that they can see the bases towards the bottom and pair them as well.

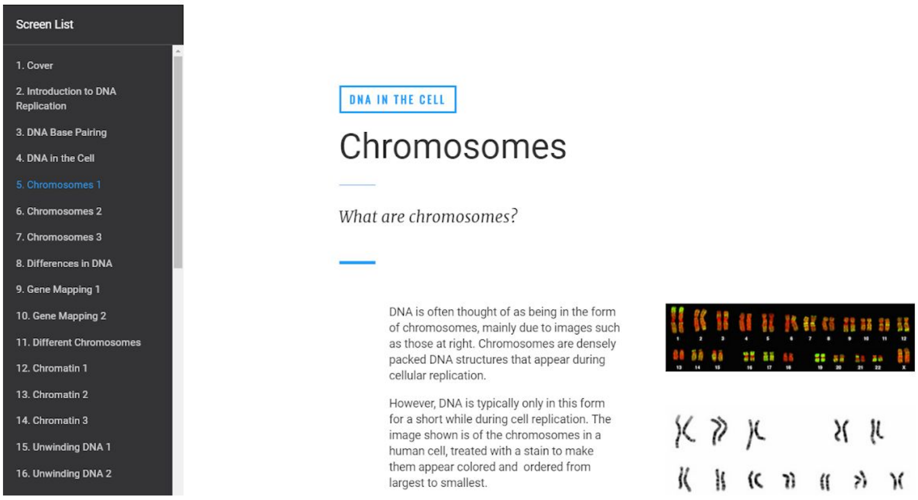
Activity Walk-through

1) DNA Base pairing (Screen 3)



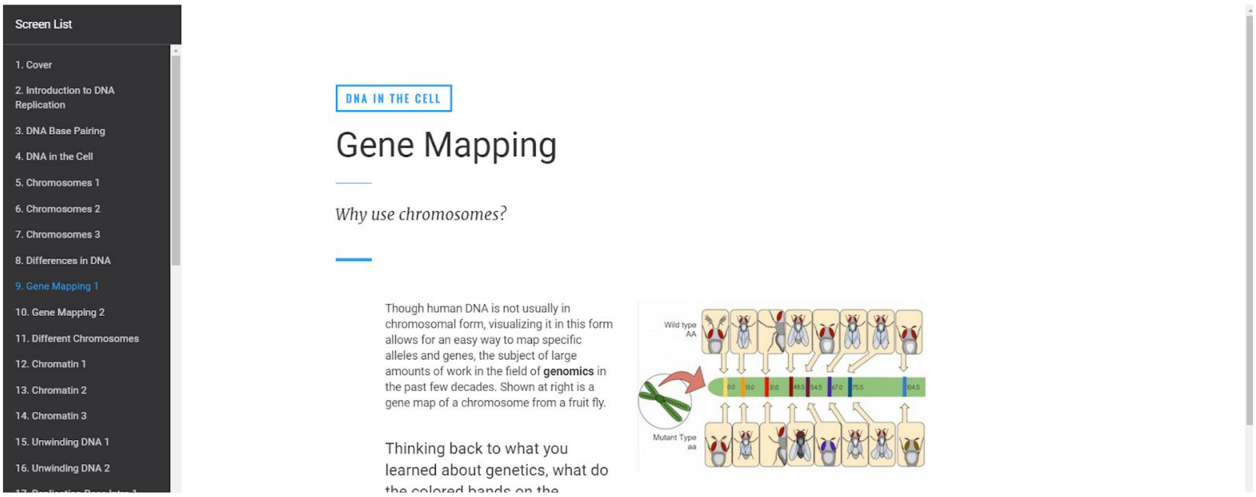
This screen asks students to pair the bases on the DNA strand. Students are provided a template with one strand of bases and they have to match those bases by adding on their pair. As students keep adding on a pair, the double stranded strands grow. As before, students will have to keep pulling the strand up so that they can see the bases towards the bottom and pair them as well.

2) Chromosomes (Screens 5-7)



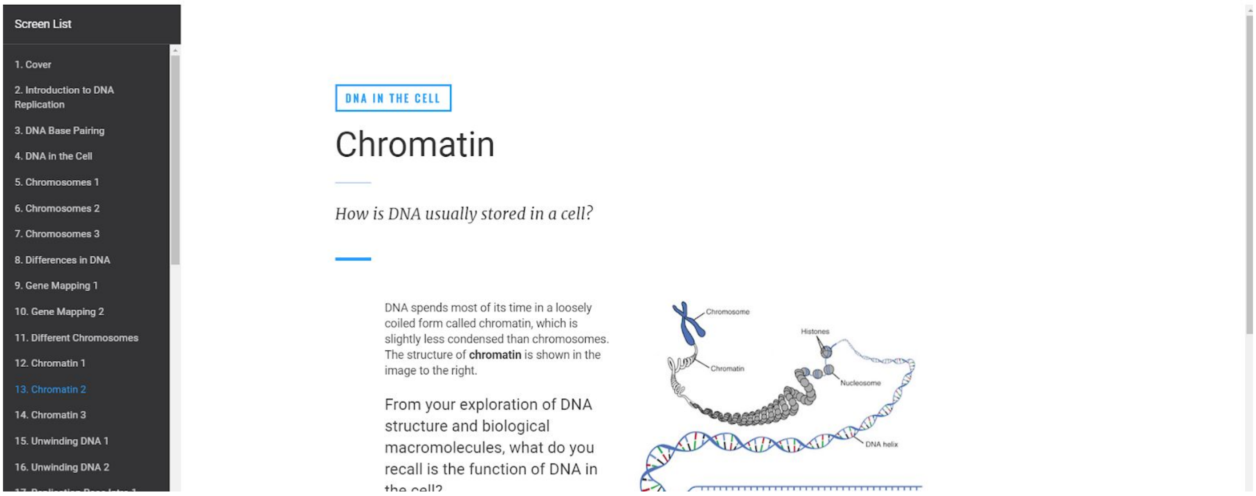
Screens 5-7 function as an introduction to the idea of chromosomes and their vast presence throughout all of known life. These screens help to scratch the surface of how DNA behaves.

3) Gene mapping (Screens 9-10)



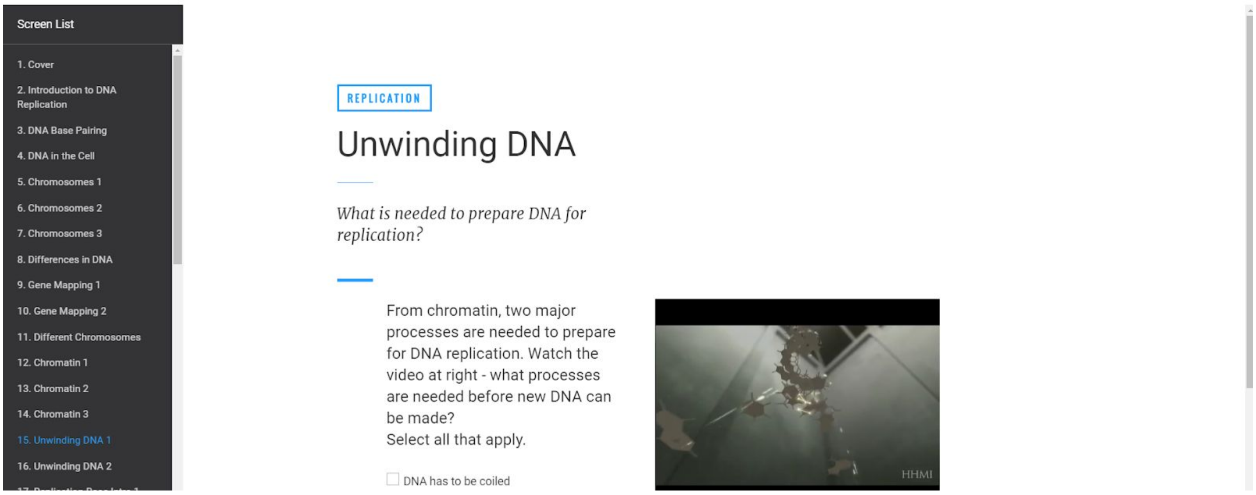
Now that the idea of a chromosome has been established, students begin to discover why chromosomes are used so prevalently throughout nature as they follow the next several screens.

4) Different chromosomes/chromatin (Screens 11-14)



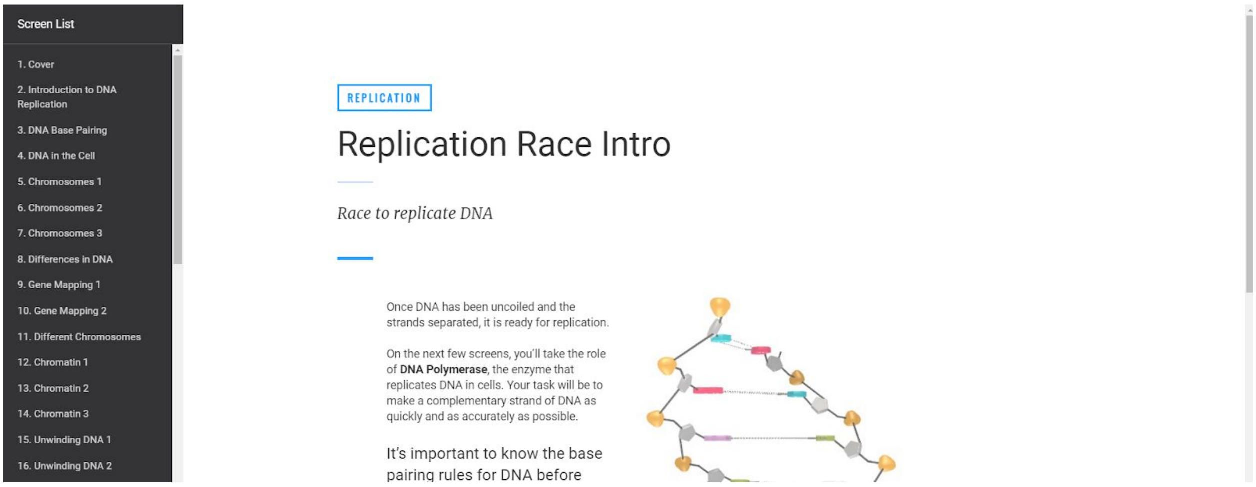
Winding deeper into the mechanics of DNA storage, students see that chromosomes are not the usual way to store DNA. Screens 11-14 show the student how chromatin works to store DNA.

5) Unwinding DNA (Screens 15-16)



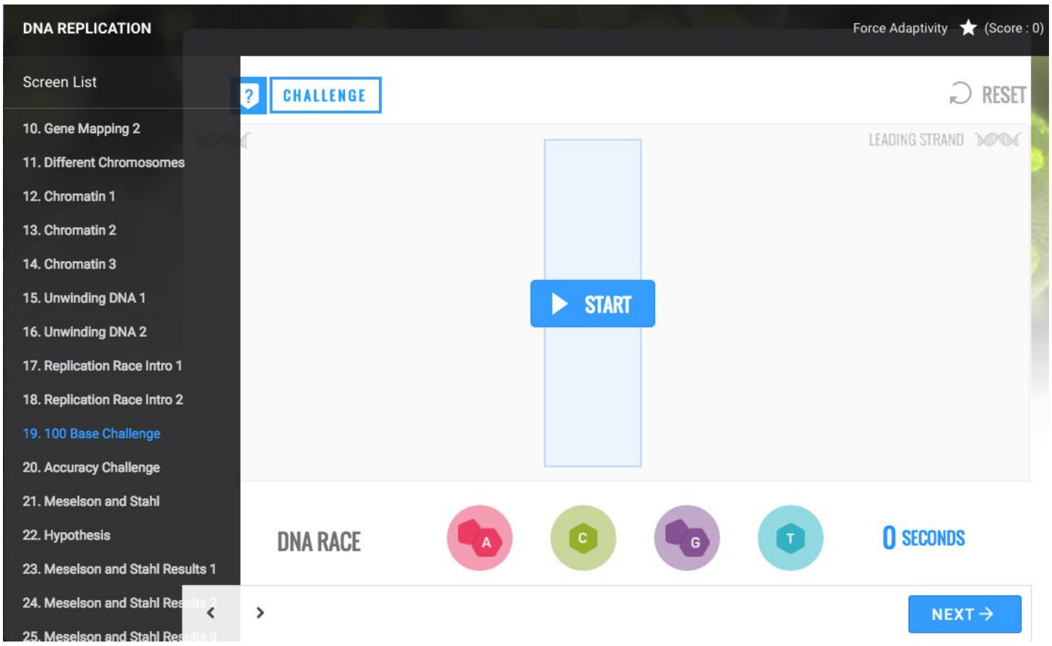
Screens 15-16 are guided by a video instruction featuring a DNA simulation. Students then follow up with some questions about DNA.

6) Replication Race (Screens 17-18)



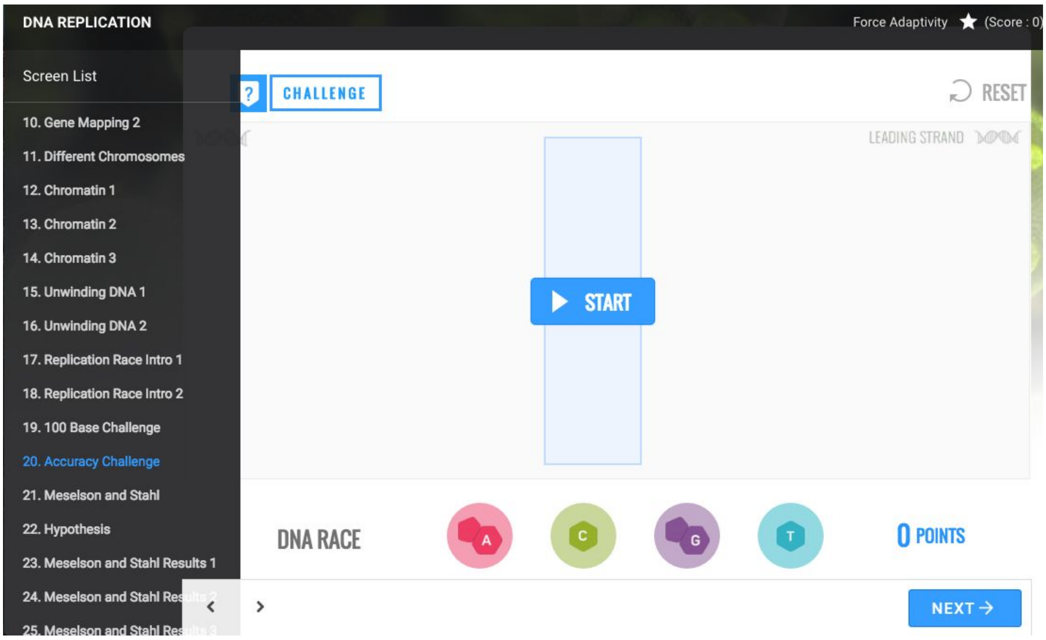
Screens 17-18 contain essential base pairing rules which the students must grasp in order to succeed in later simulations featured within this unit.

7) 100Base Challenge (Screen 19)



Students are asked to pair 100 bases as fast as they can with as much accuracy as possible. The timer will keep going as the students are pairing the bases together. At the end, if the student has made 25 or more mistakes or has repeated the same letter in succession, they will be told to try again.

8) Accuracy challenge (Screen 20)



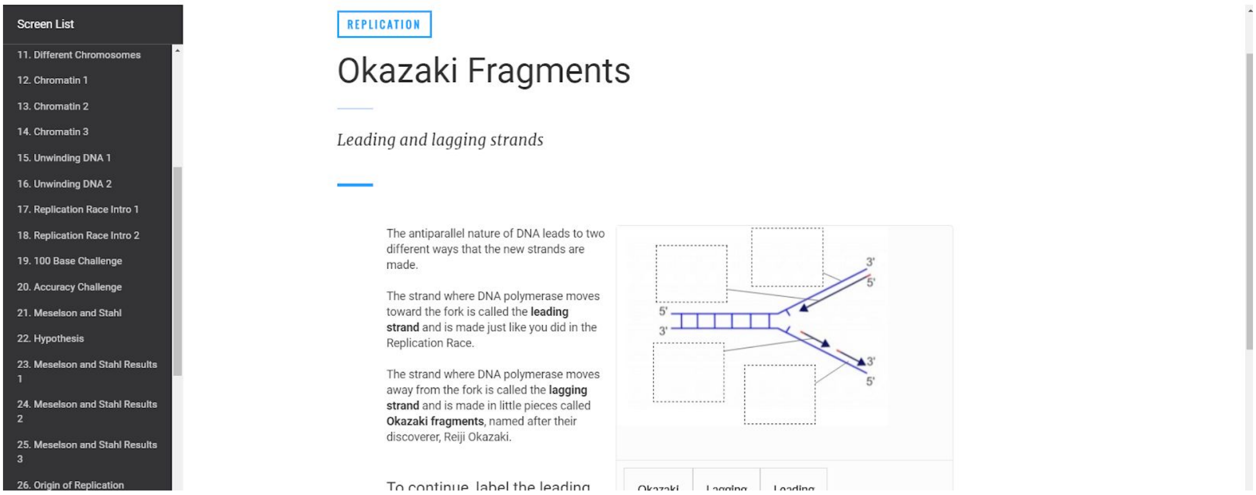
Like the screen before, students will be asked to pair bases again. This time, the strand will keep moving and students will have to rapidly determine the correct base pair and match accordingly. They will not have time, like on the previous screen, to work through each pair as they see fit. They will be on a time crunch and can get very stressed. If five mistakes are made the activity accelerates and students will be asked to try again.

9) Meselson and Stahl (Screens 21-25)

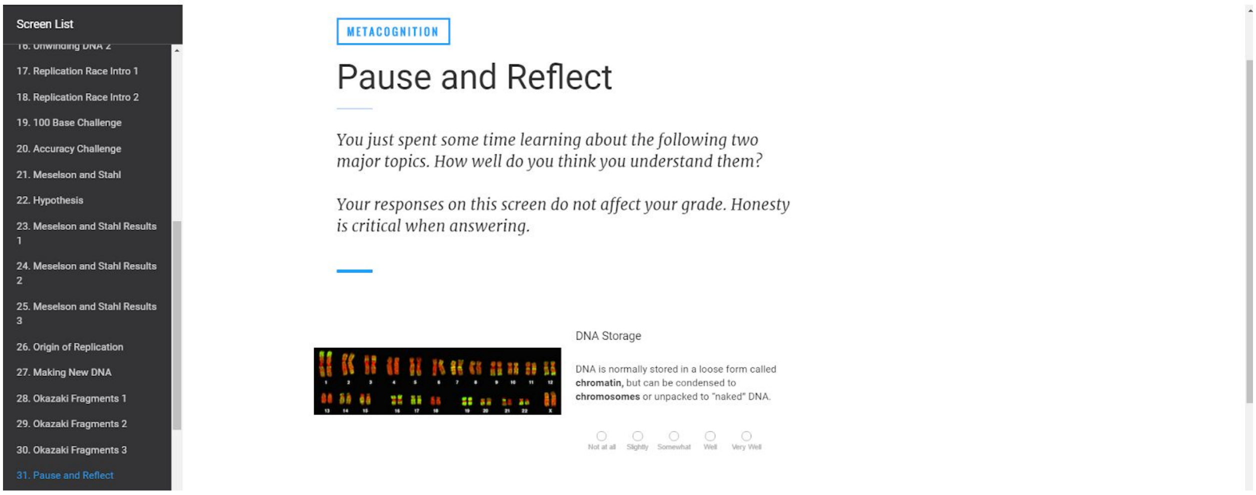
Students explore the famous Meselson and Stahl experiment in the next several screens and compare different ideas of how DNA replication could happen in nature.

Guided by the visualization on the right side of the screens, students answer questions at the heart of this experiment and learn how simple chemistry can be used to bust big mysteries. Students continue to learn about the origins of replication and continue on to the Okazaki part of the instruction.

10) Okazaki Fragments (Screens 28-30)

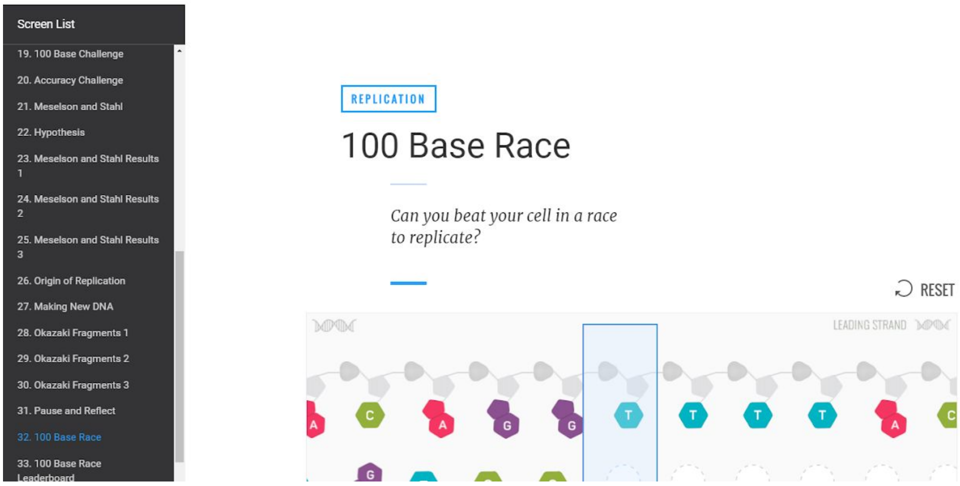


Here, students will be tasked with labeling the leading and lagging strands of a DNA replication fork. Further questioning delves deeper into the concepts of “leading” and “lagging”, as students see that building DNA can be a little trickier than it may seem.



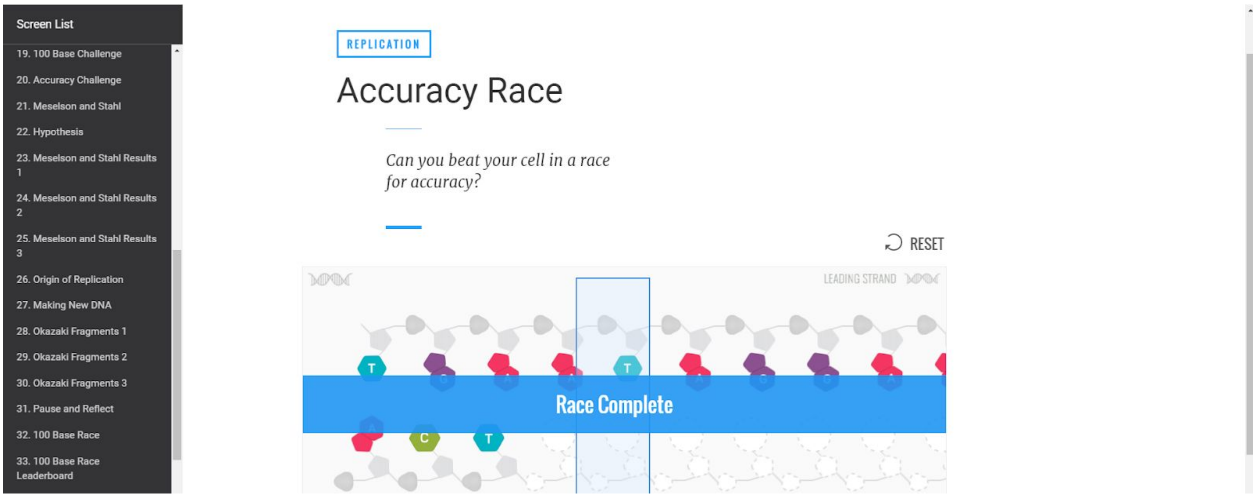
A brief metacognition screen allows the students to reflect on their understanding so far before they move advance into the DNA Race!

11) 100 Base Race (Screen 32)



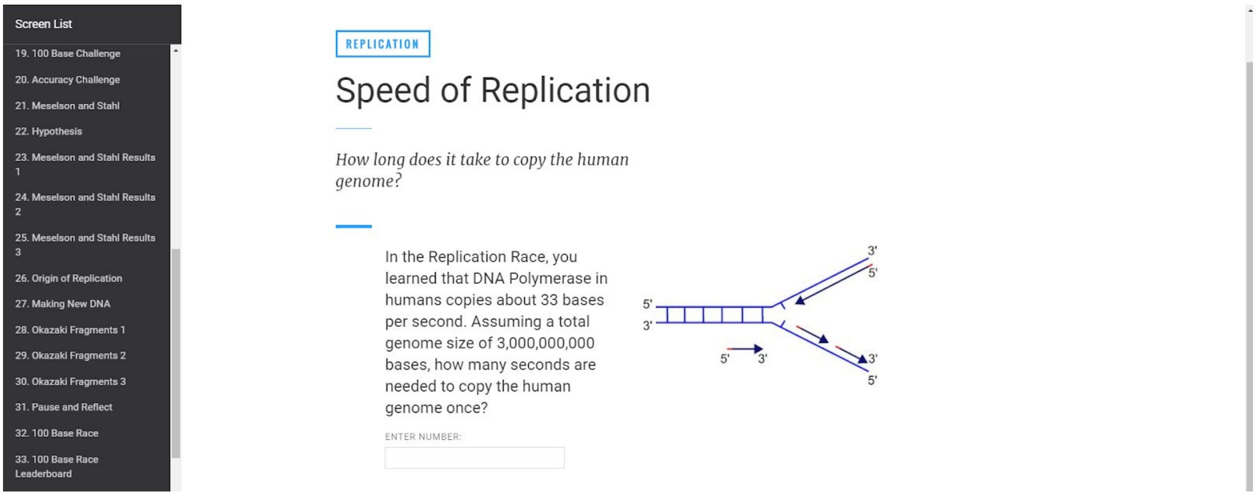
Students are challenged with a '100 base race' wherein the appropriate bases must be quickly matched in succession.

12) Accuracy Challenge (Screens 34-35)

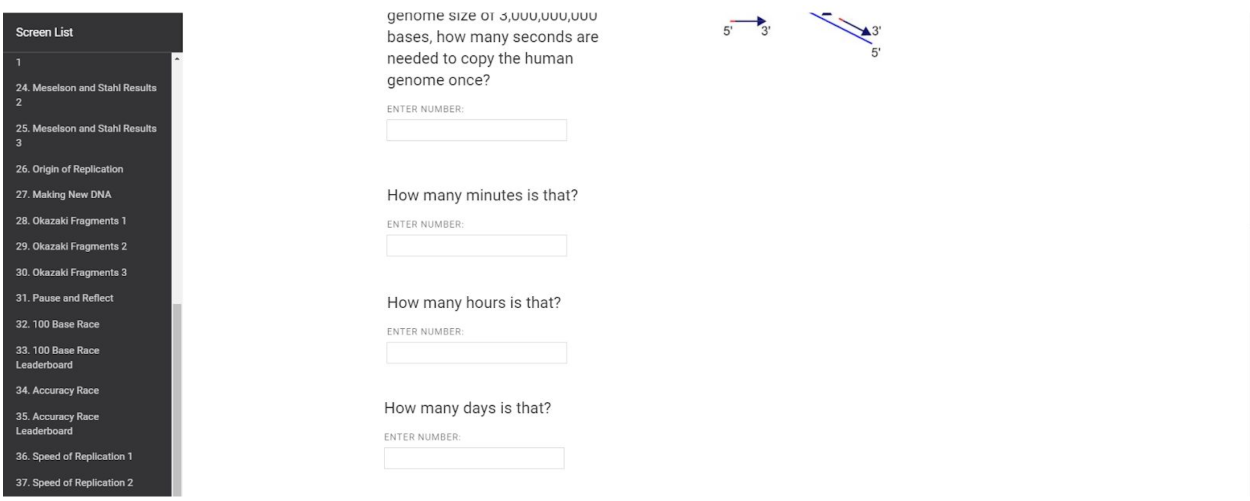


Now students must be quicker than ever in their understanding of nucleotide bases as they rush against the simulation to stack up the correct bases of DNA.

13) Speed of replication (Screens 36-40)

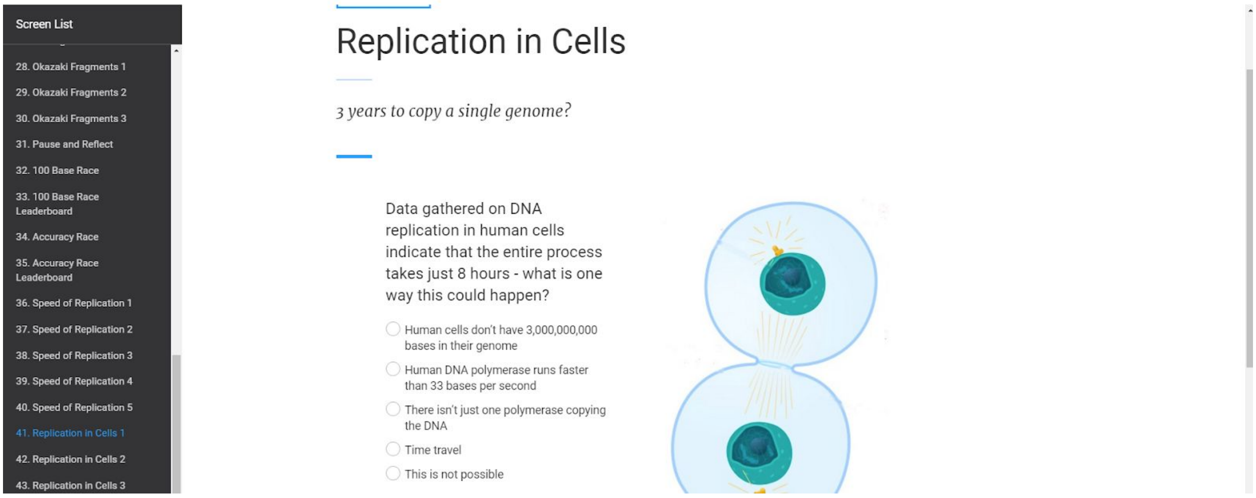


Now that students have tackled some more DNA basics, they are guided by some basic arithmetic in understanding the speed at which DNA replicates itself.

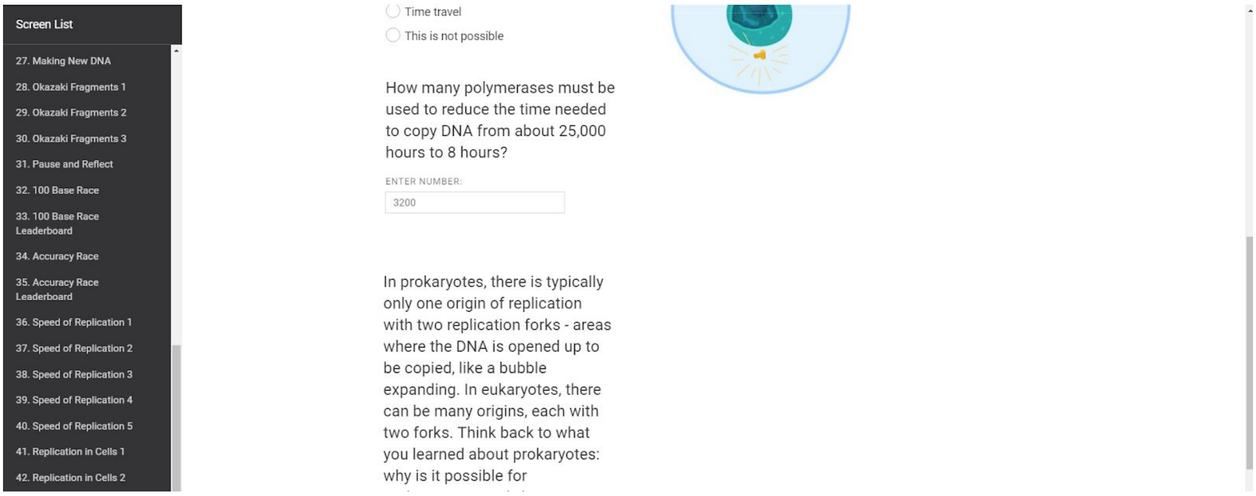


Students may use methods such as dimensional analysis or a calculator to provide answers to these questions.

14) Replication in Cells (Screens 41-43)

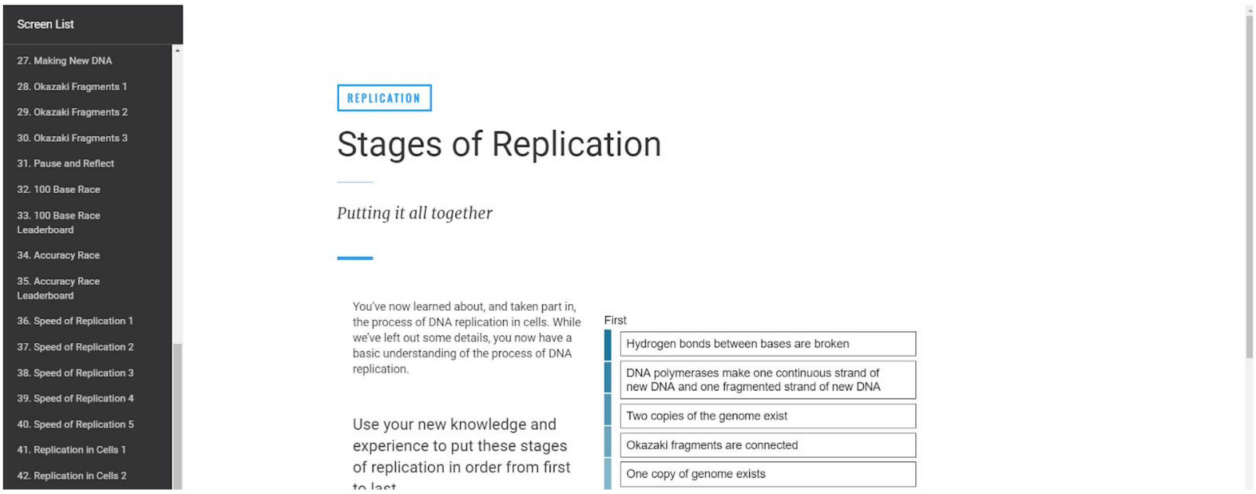


The next several screens are intended to help the student understand how genome replication works in the real world.



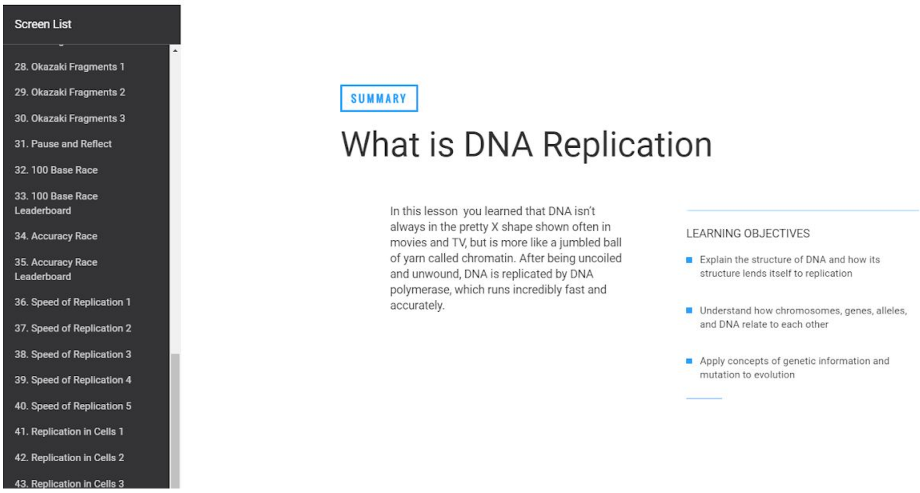
Screen 43 segways into the last portion of this instruction: Stages of Replication.

15) Stages of Replication, Screens 44-45.



Screens 44-45 present the stages of replication and the student is tasked with ordering them correctly to reinforce the concept of DNA replication.

16) Summary (Screen 46)



Screen 46 concludes this portion of instruction as students now move into the next section.

Unit 6 Searching for Signatures: DNA Function — Making Proteins

Lesson Stats

- Average time spent: 1.5 hours

Learning Objectives

- See Instructor's Guide

Assessment

Max score: 200

Lesson Flow

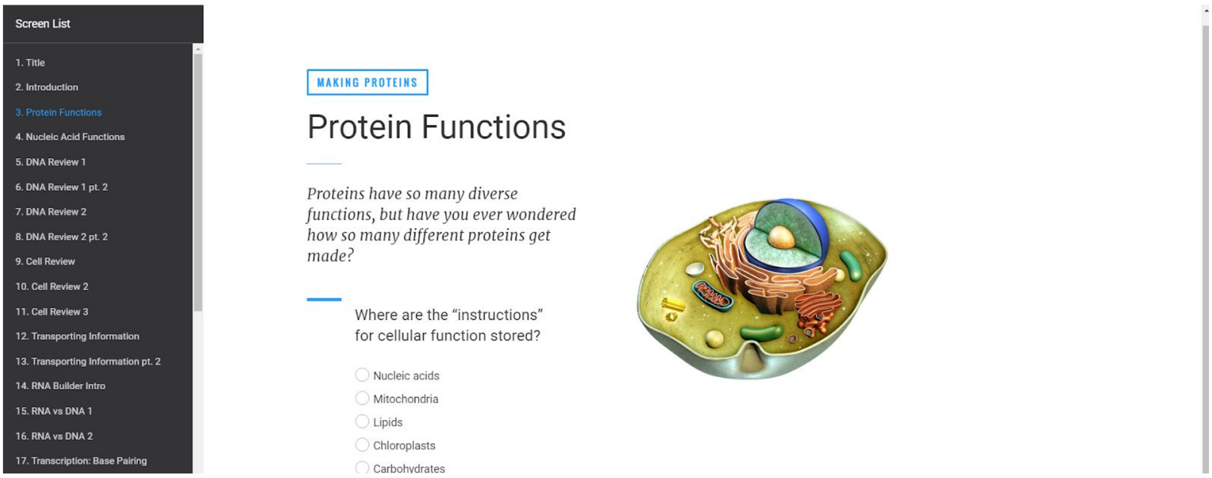
- Introduction, Screens 1-2.
- Protein functions, Screen 3.
- Nucleic Acid functions, Screen 4.
- DNA Review, Screens 5-8.
- Cell Review, Screens 9-11.
- Transporting Information, Screens 12-13
- RNA vs DNA (Transcription), Screens 14-16.
- Transcription, Screens 17-24.
- Translation, Screens 25-31.
- Central Dogma, Screens 32-34.
- Exons and Introns, Screens 35-36
- Reflection and Summary, Screens 37-38.

Common Student Issues/Misconceptions

-

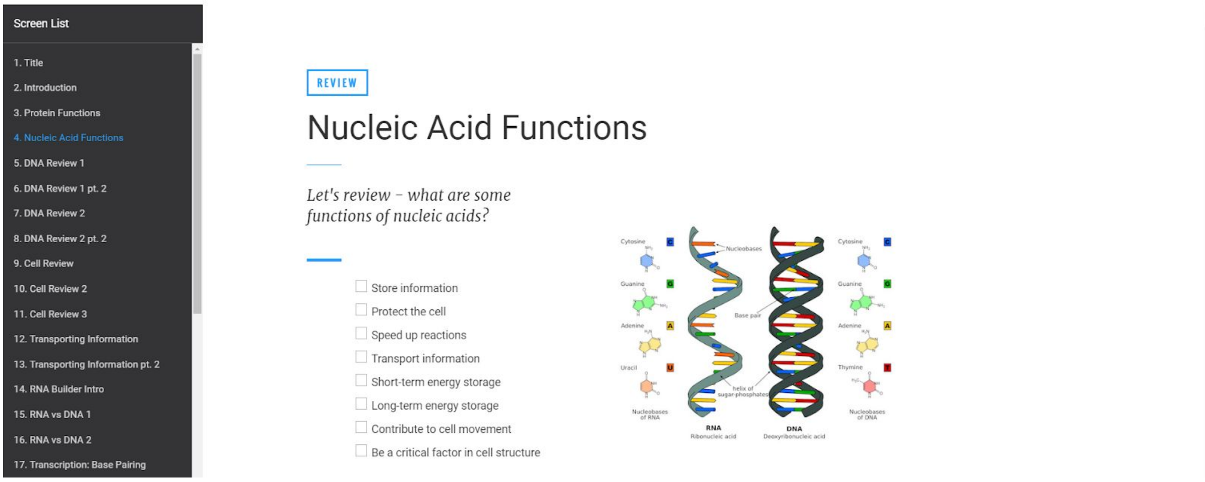
Activity Walk-through

1) Protein Functions, Screen 3



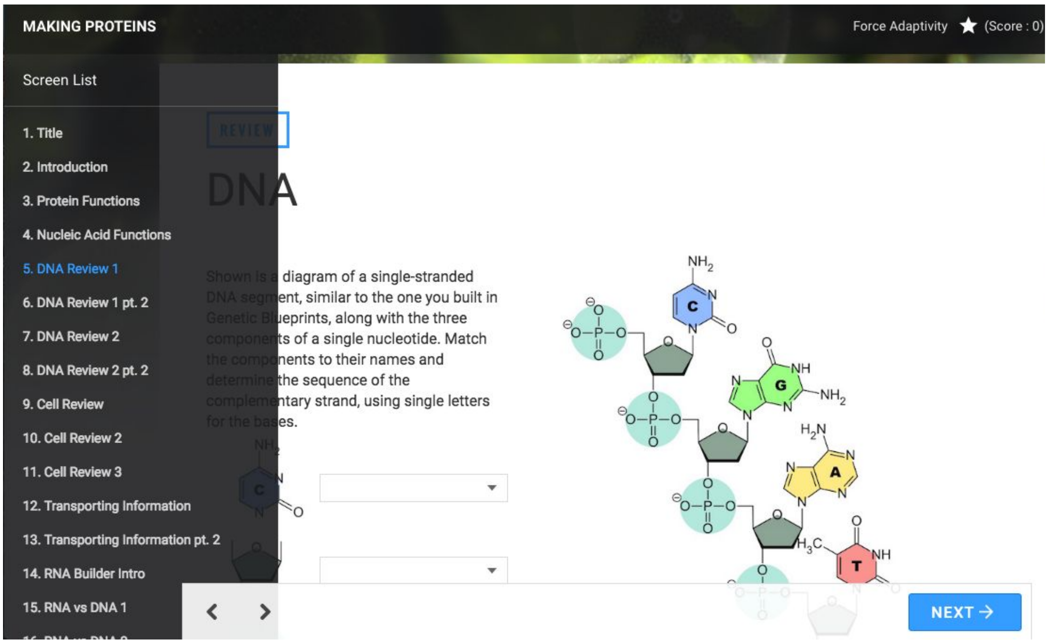
Students start to learn about functional parts of the cell, beginning with protein function. This serves as a precursor to learning about nucleic acid functions.

2) Nucleic Acid Functions, Screen 4

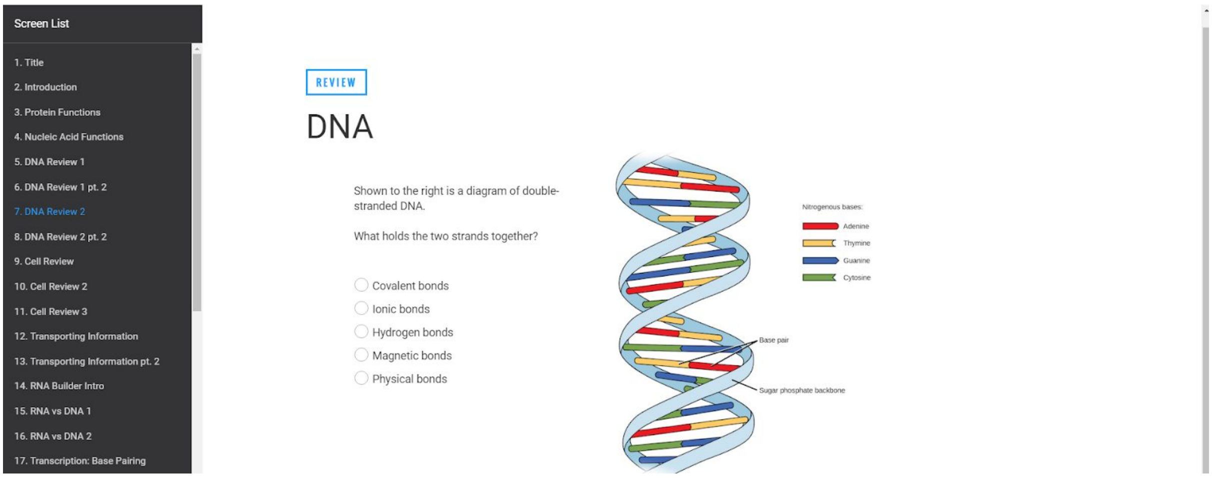


This screen features a multiple choice question which reviews the student's understanding of the functions of nucleic acids before recapping DNA.

3) DNA Review (Screens 5-8)

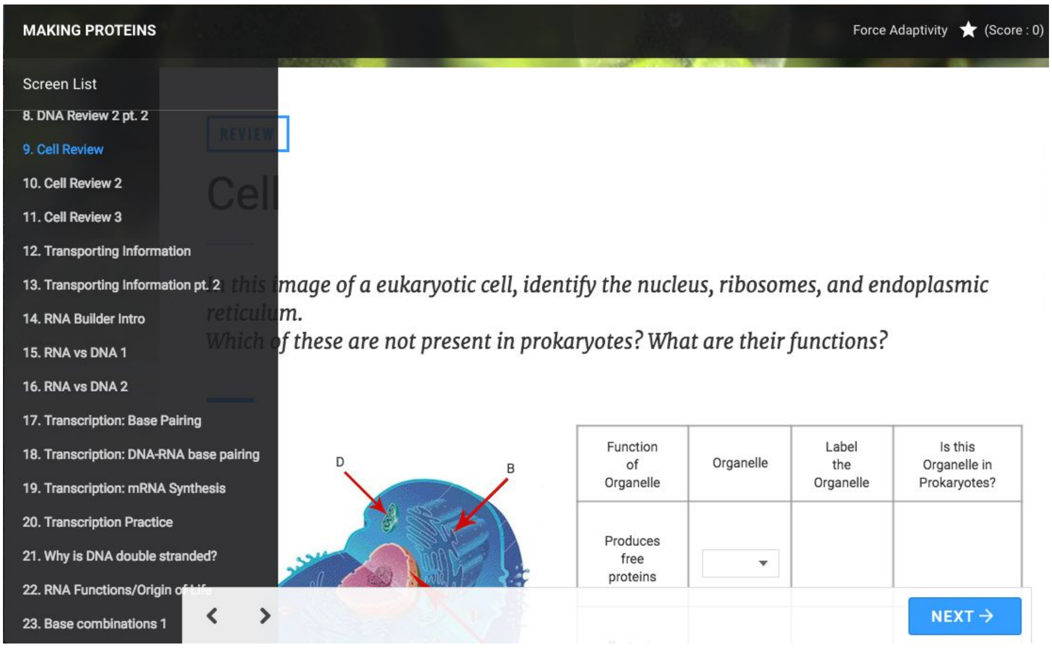


Students will be asked to use their prior knowledge from previous lessons and re-apply them here to answer questions about DNA; this activity reinforces the biochemistry of DNA mentioned previously.



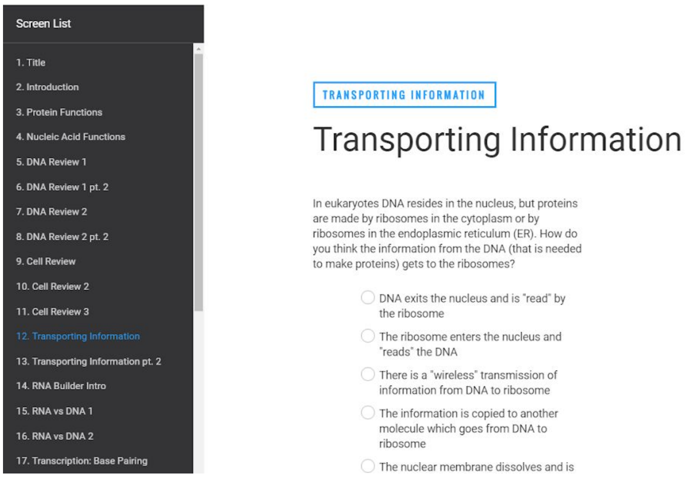
The review of DNA expands into the chemical bonds present in the structure of DNA. By solidifying the basic features of DNA, the DNA review screens help prepare the student to tackle tougher concepts which appear later in this section.

4) Cell Review (Screens 9-11)



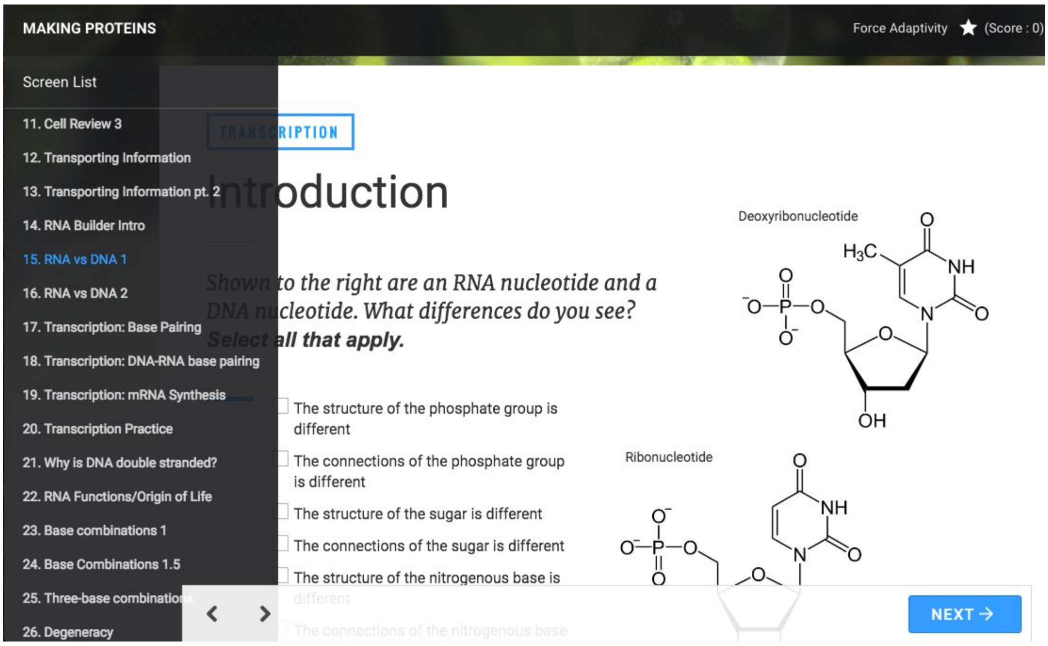
Students will use their prior knowledge from previous lessons in order to fill in the boxes as they progress through different categories of questions. The provided model serves as a 3D view of where the organelles are and engages the student to think about the moving parts of a cell.

5) Transporting Information (Screens 12-13)



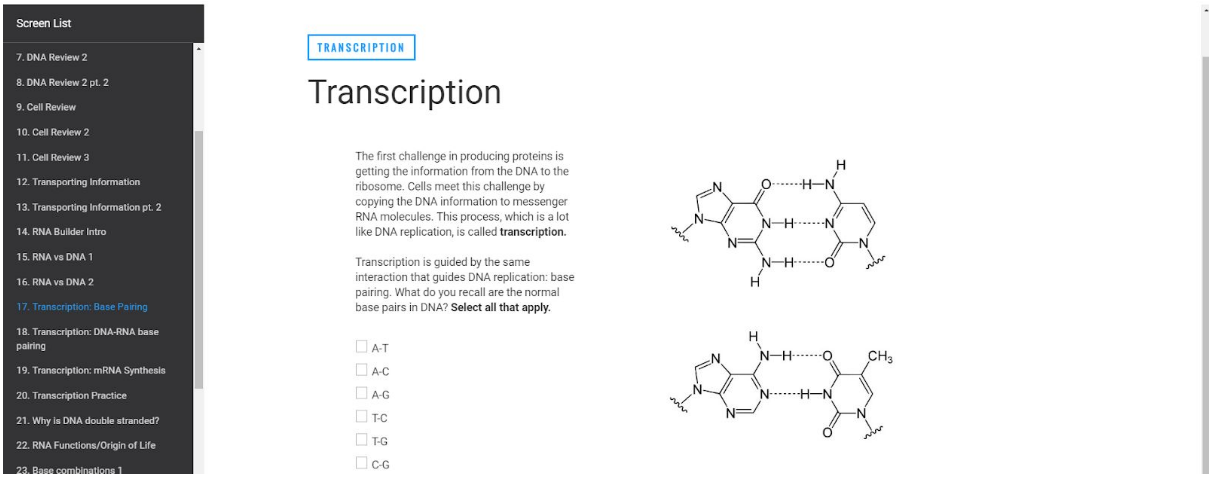
Now that the student has reviewed the basic physical structure of a cell, screens 12-13 probe the student's grasp of the inner mechanics of cell behavior and how information is transported. These screens prime the student to compare DNA and RNA in the following screens

6) RNA vs DNA (Screen 15)

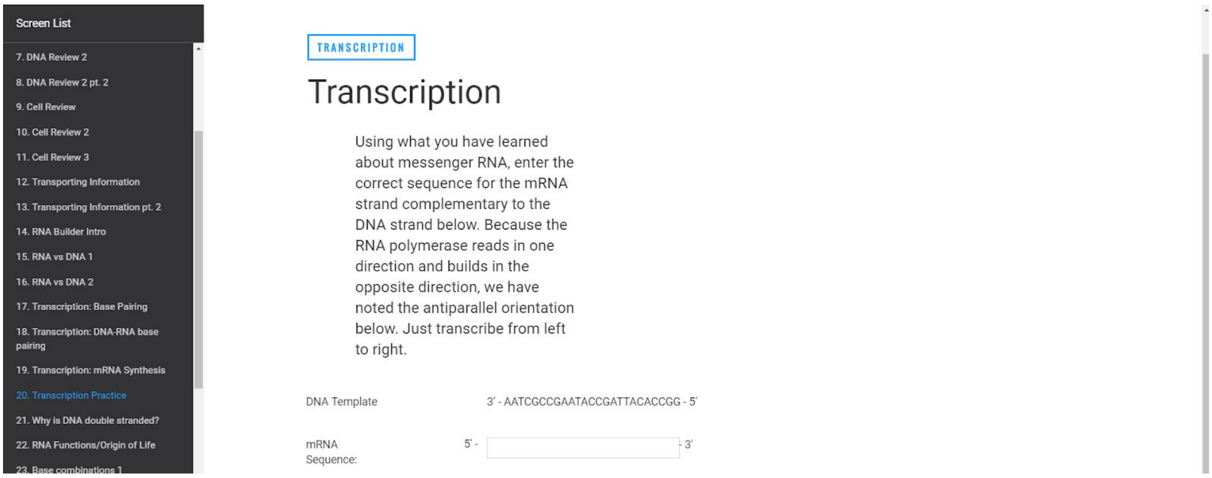


Students must be able to differentiate between RNA and DNA by understanding the chemical makeup of each biomolecule. These screens plant the question of why both DNA and RNA common to all lifeforms, as students venture into understanding how these molecules shape all of life.

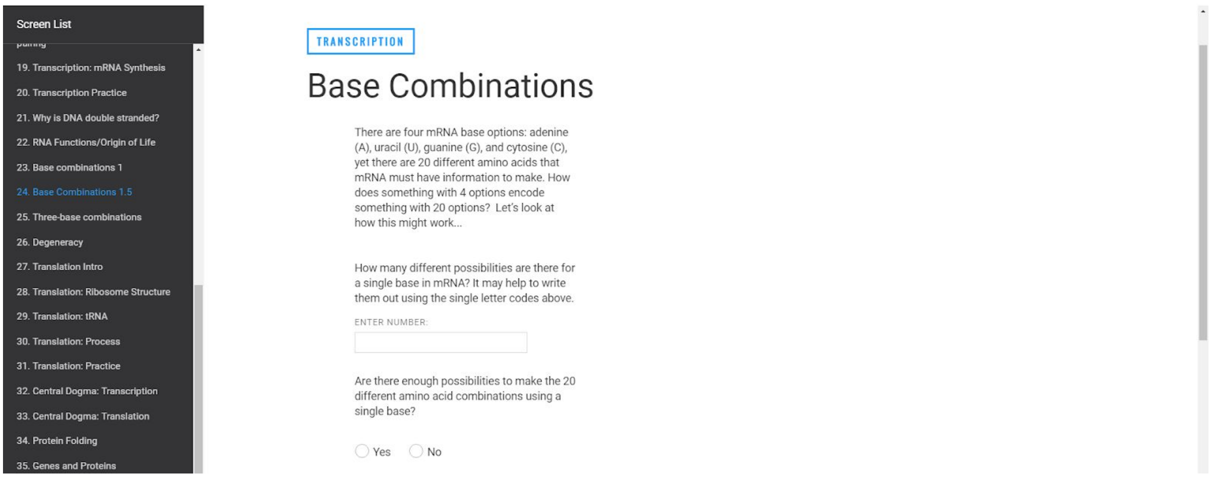
7) Transcription (Screens 17-24)



Student utilize previous knowledge in order to begin learning about transcription.

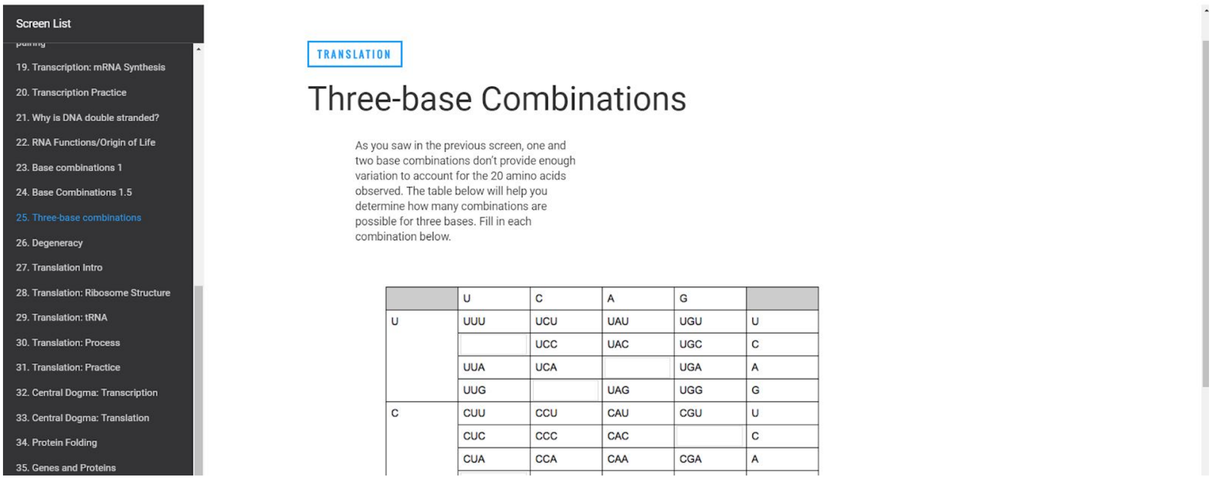


After unwinding through the process of transcription, the student's understanding of the process is tested as they are prompted to transcribe DNA into RNA.

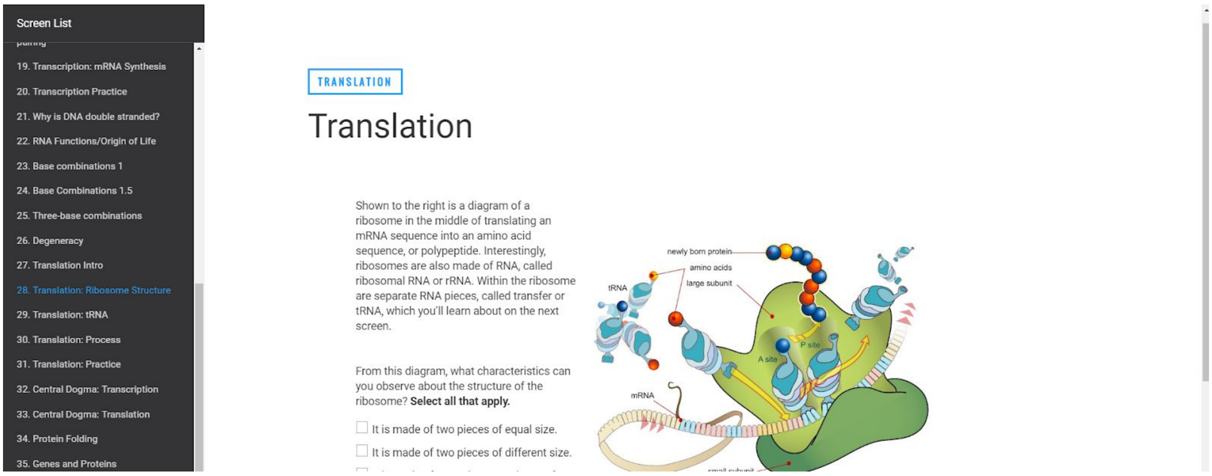


In the next series of screens, the student applies knowledge of nucleic acids, bases, and uses arithmetic to answer questions about protein synthesis. This segways into the process of translation covered during the next several screens.

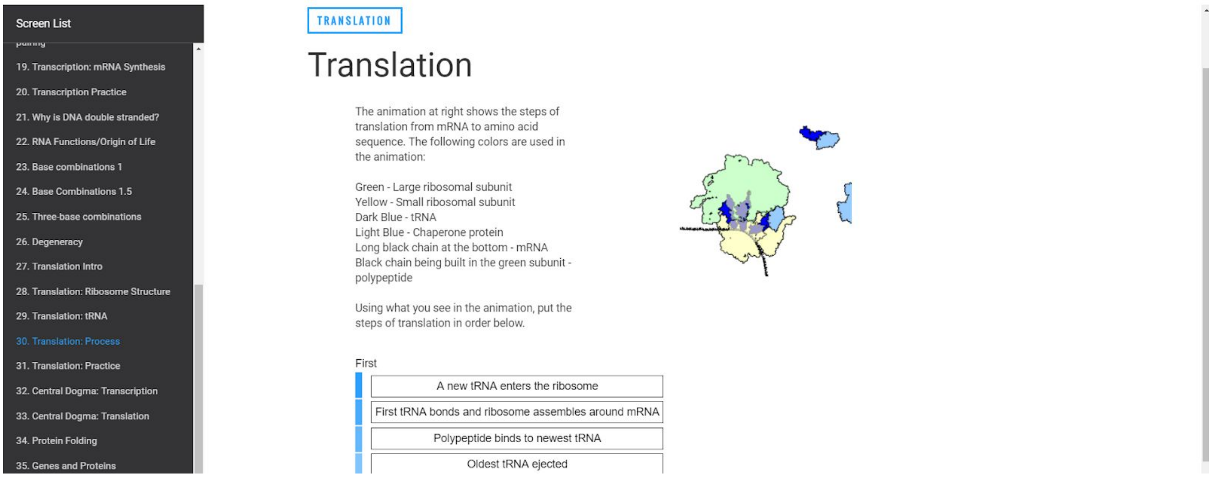
8) Translation (Screens 25-31)



The students are shown a codon table which provides all possible codon combinations for RNA. Several blank boxes are shown for the student to fill in by using the table as a guide. Students then go on to learn about the advantages of genetic degeneracy in the next screen before delving into protein synthesis.

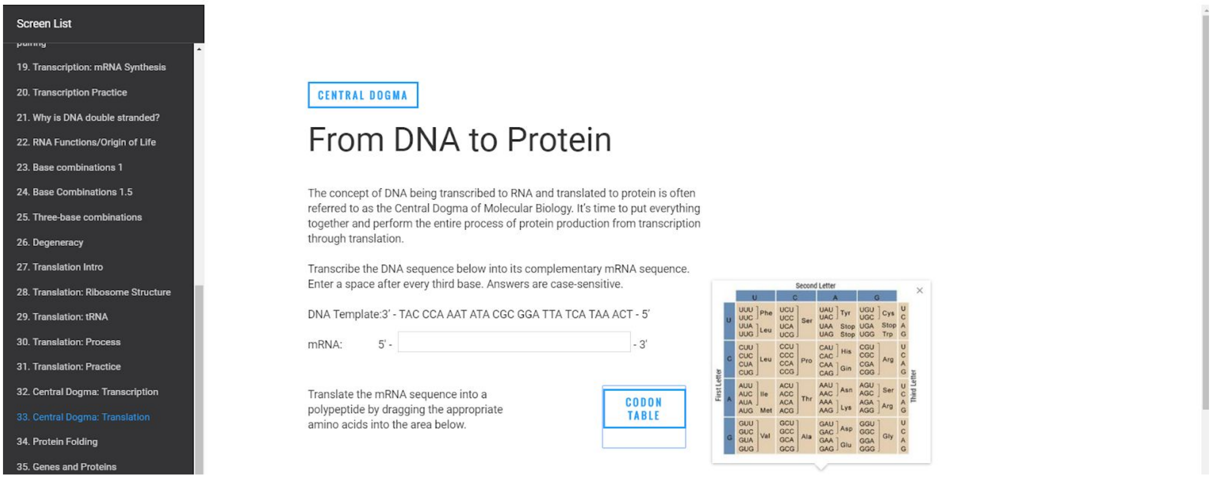


Exploring into the ribosomal subunit, students begin to capture how a string of nucleotides can be transformed into the functional products which are common throughout all of life.



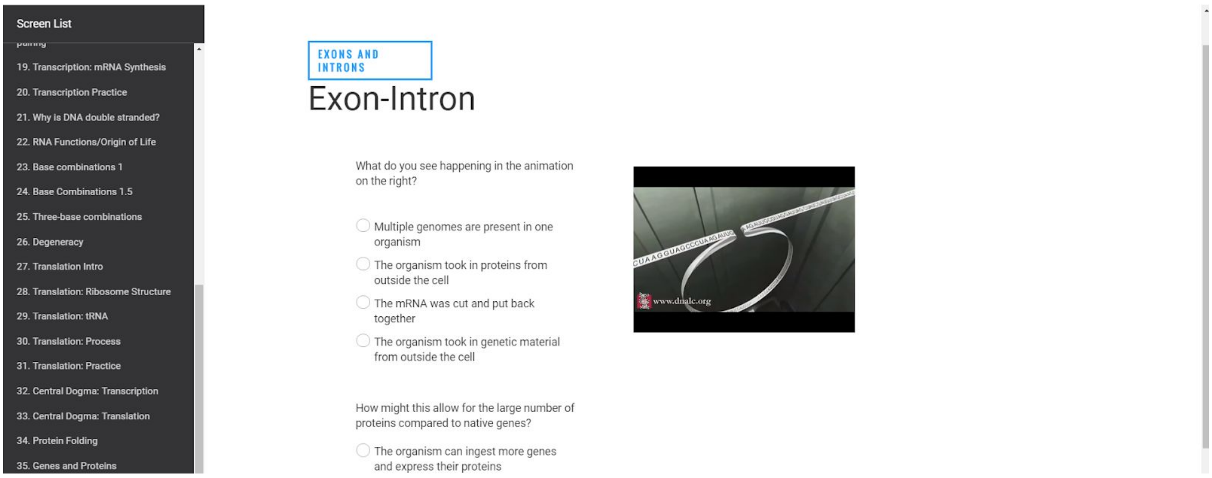
This simulation guided screen challenges the student to order the translational processes correctly, and provides a legend for each of the colored segments of the simulation. This is intended to animate the process of translation so that the student can see the mechanics of how proteins are built.

9) Central Dogma (Screens 32-34)



Screens 32-34 function as reviews for the major elements of both transcription and translation and are intended to reinforce the central tenants of both processes. Screen 34 shows 3D protein folding and serves as another visualization that the end product is a functional unit.

10) Exons and Introns



Screens touching on Exon/Introns include a video which graphically illustrates the idea of splicing, and shows how introns and exons function within the genetic code. This screen concludes the instructional portion of this section as students reflect on the learned material and move into the next unit.

Unit 7 Blue Planet: Our Blue Planet

Lesson Stats

- Average time spent: 1.5 hours

Learning Objectives

- Students explore the past and present of our home and project into the future and organize their journey to see the big picture.
- Students will build their own Blue Planet Report as they gather evidence, identify patterns, and draw conclusions.

Assessment

Max score: 100

Lesson Flow

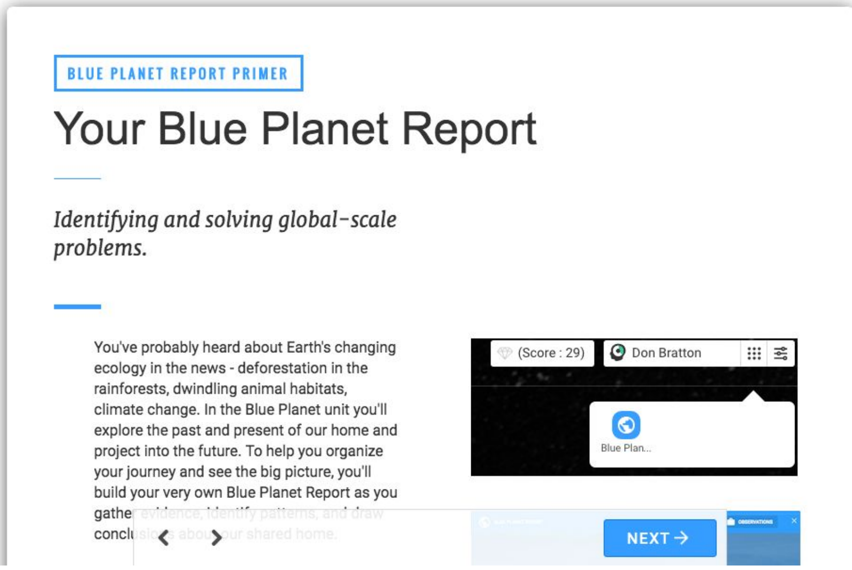
- Introduction, Screens 1-2.
- Your Blue Planet Report, Screen 3.
- Adding Observations, Screen 4.
- Blue Planet Report Sections, Screen 5.
- Liquid Water on Earth, Screen 9.
- Energy Balance Sim, Screens 12-17.
- Car Scenario, Screens 18-22.
- Atmosphere, Screens 23-25.
- Putting it all Together, Screen 26.

Common Student Issues/Misconceptions

- Some students have issues with setting up the temperature simulation. It is critical for them to insert the correct parameters in the correct areas.

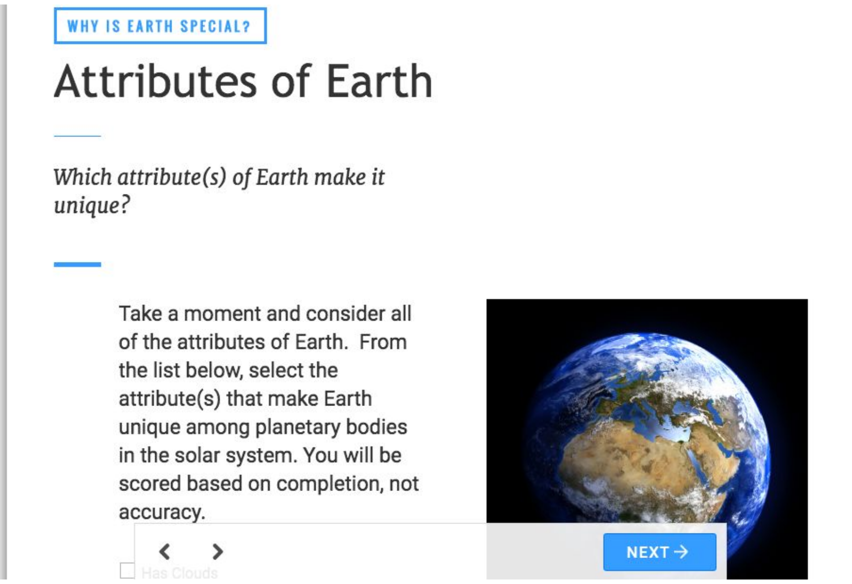
Activity Walk-through

1) Your Blue Planet Report, Screen 3



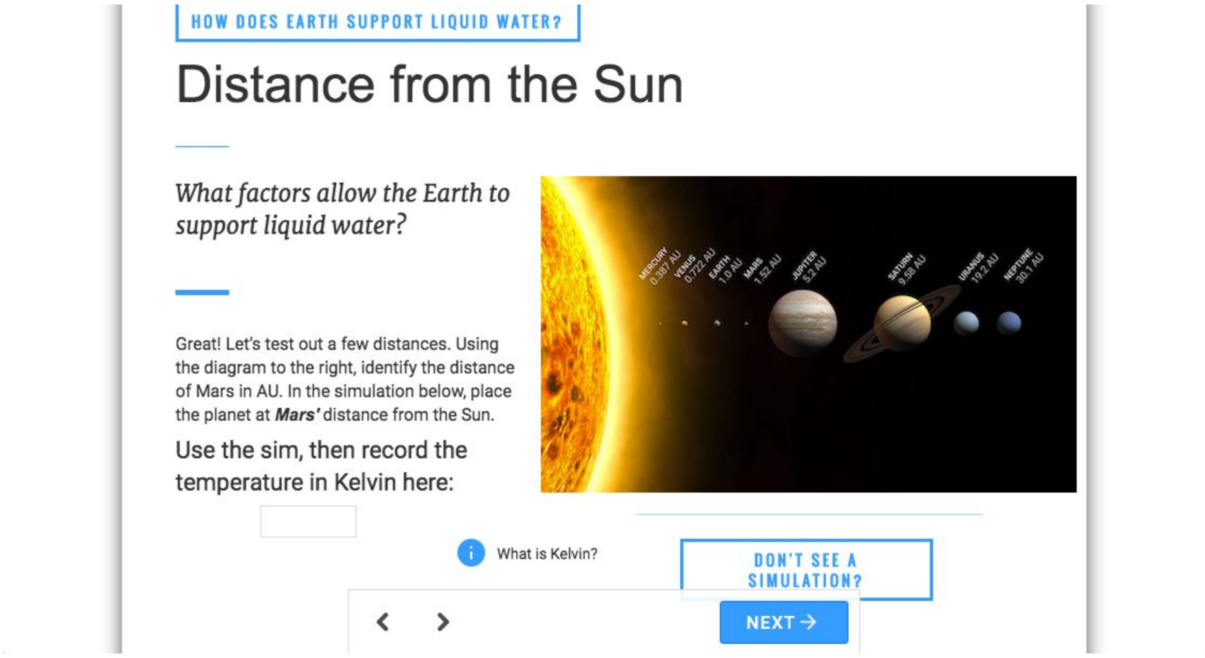
Students are asked to organize their journey and see the big picture by building their own Blue Planet Report as you gather evidence, identify patterns, and draw conclusions about our shared home.

2) Why is Earth Special, Screen 7



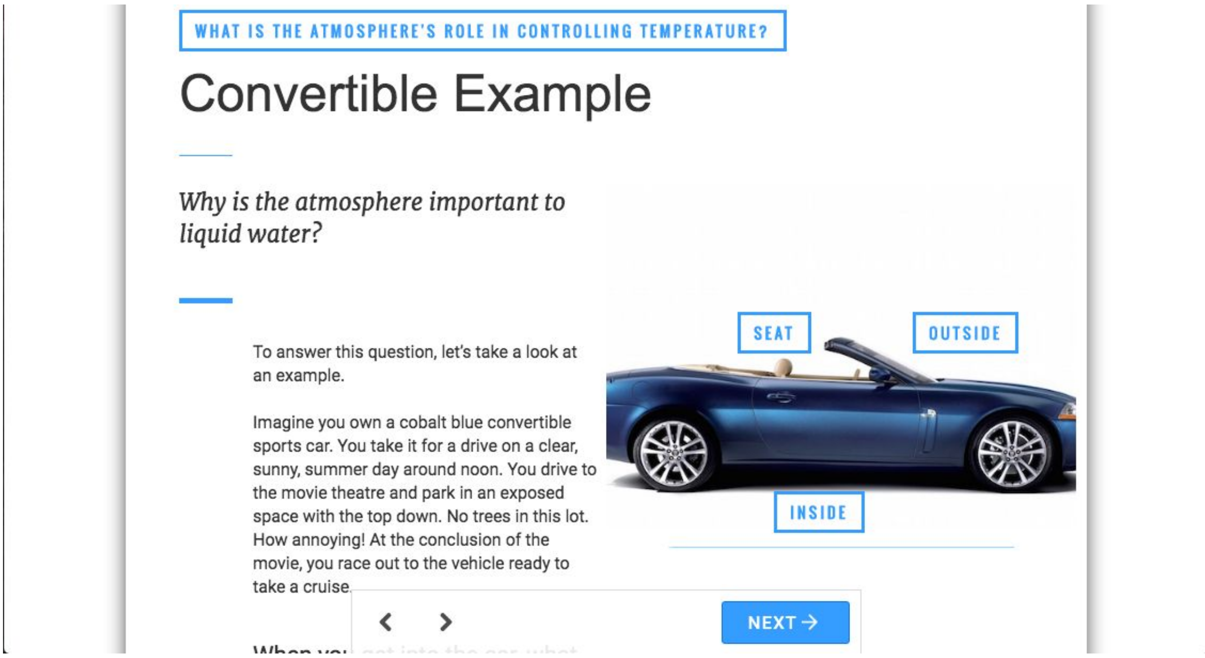
Students are asked to select the attributes that make Earth unique among planetary bodies in the solar system.

3) Energy Balance Sim - Mars Distance



Students are asked to use the simulation to record the temperature. This will help them with the subsequent slides, where they will be asked to use simulations to answer more questions.

4) Car Scenario - Top Down, Screen 18



This is the beginning of the Car Scenario where students use a car to determine the atmosphere's role in controlling temperature.

Unit 7 Blue Planet: History Repeats Itself,With A Twist

Lesson Stats

- Average time spent: 1.5 hours

Learning Objectives

- See Instructor's Guide

Assessment

Max score: 163

Lesson flow

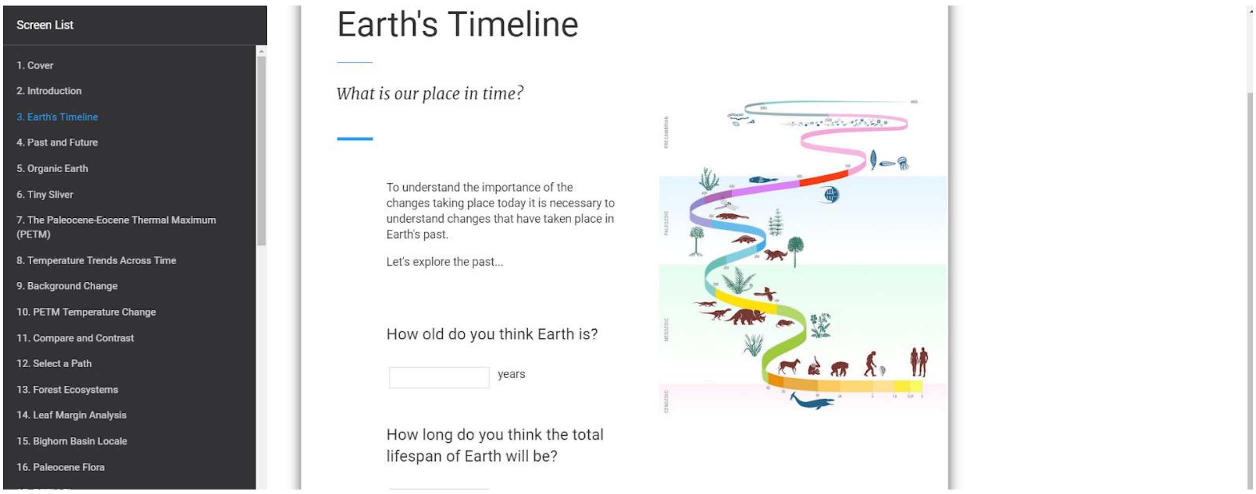
- Introduction and Background, Screens 1-12.
- Forest Ecosystems, Screens 13-22.
- Insect Herbivory, Screens 23-39.
- Coral Reefs, Screens 41-48
- Consequences of a Warming World and Conclusion, Screens 49-54.

Common Student Issues/Misconceptions

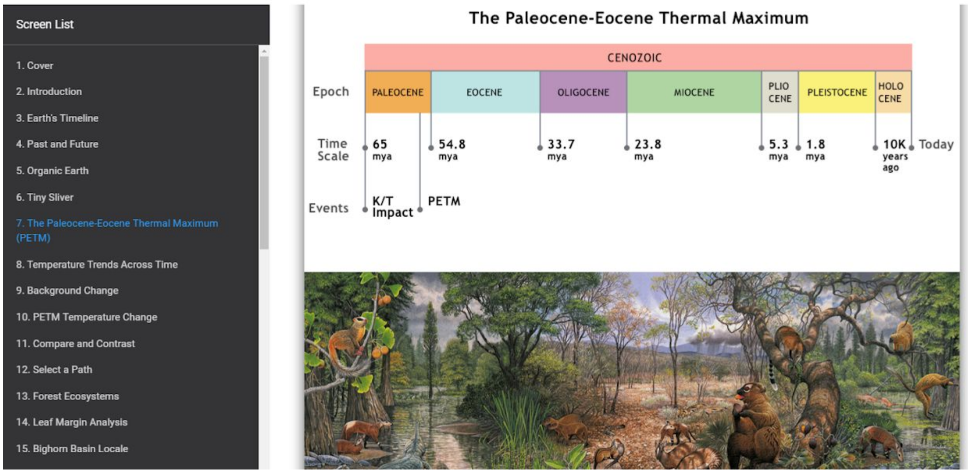
- Students have had significant difficulty with the insect herbivory activity, often over-analyzing the images.

Activity Walk-through

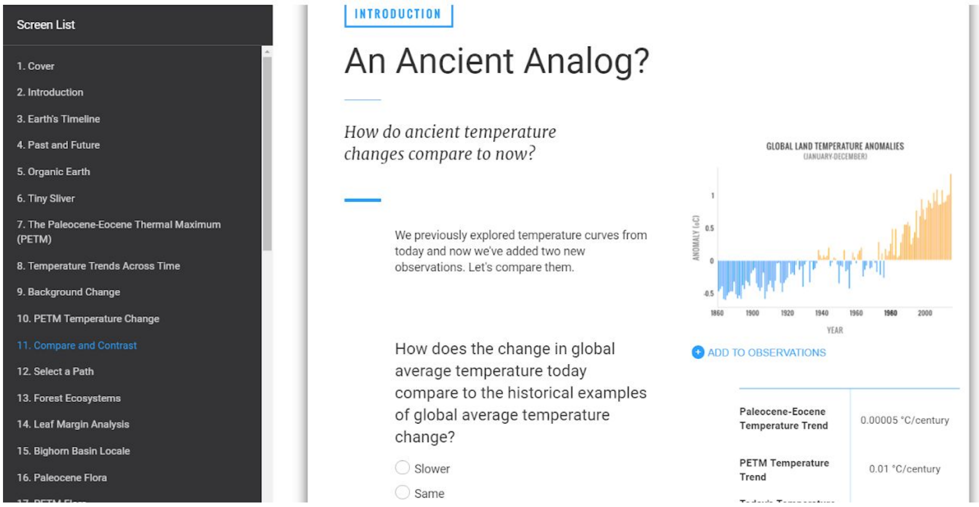
1) Introduction and Background (Screens 1-12)



In the introductory screens, students contemplate the past features of Earth and explore them through an interactive timeline as well as several additional questions which guide the student into learning about the PETM.



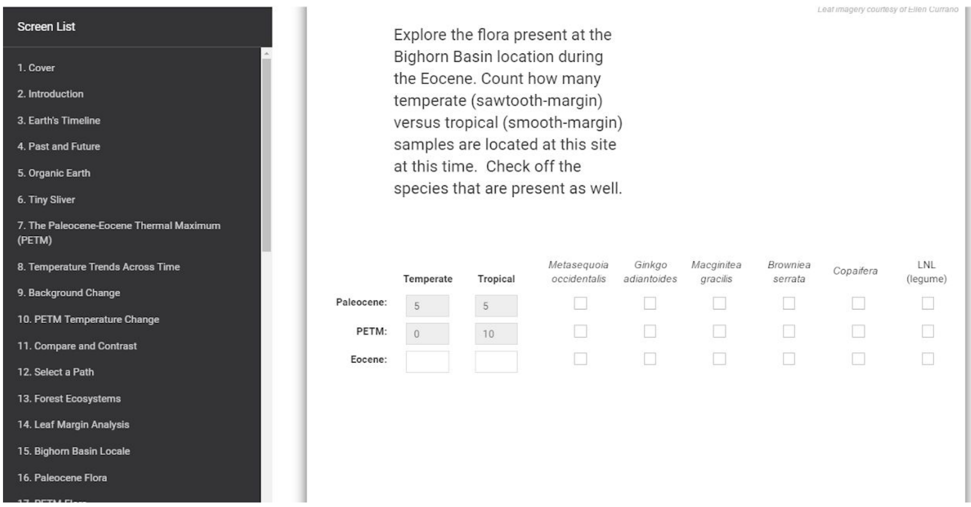
Screen 7 introduces the PETM with a scaled timeline of the Cenozoic Era, as the student is primed to learn about temperature trends over time.



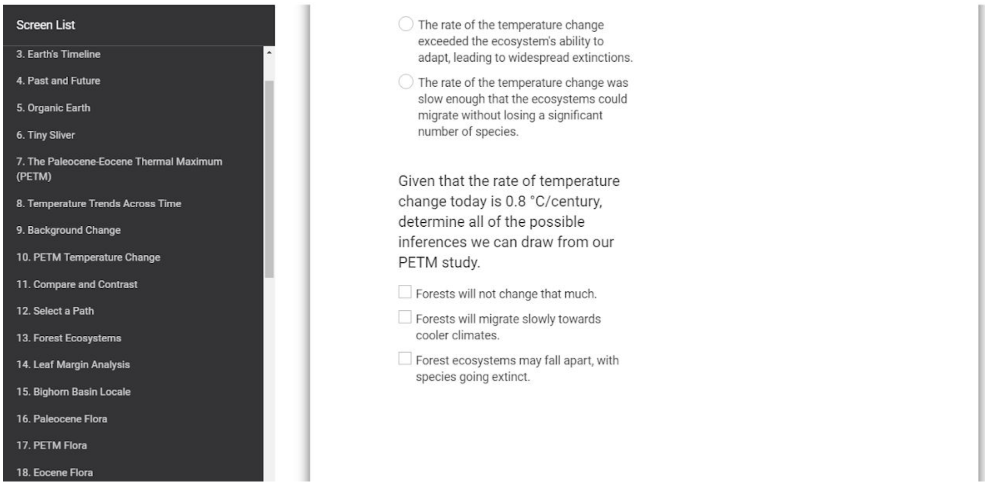
The introductory instruction closes out with a brief compare and contrast segment as the students prepare to select a path in order to begin learning about biome change during the PETM.

2) Forest Ecosystems (Screens 13-22)

Screens 13-22 take the student on a journey through ancient forests, wherein the student is expected to understand certain ecological features which once existed on Earth.

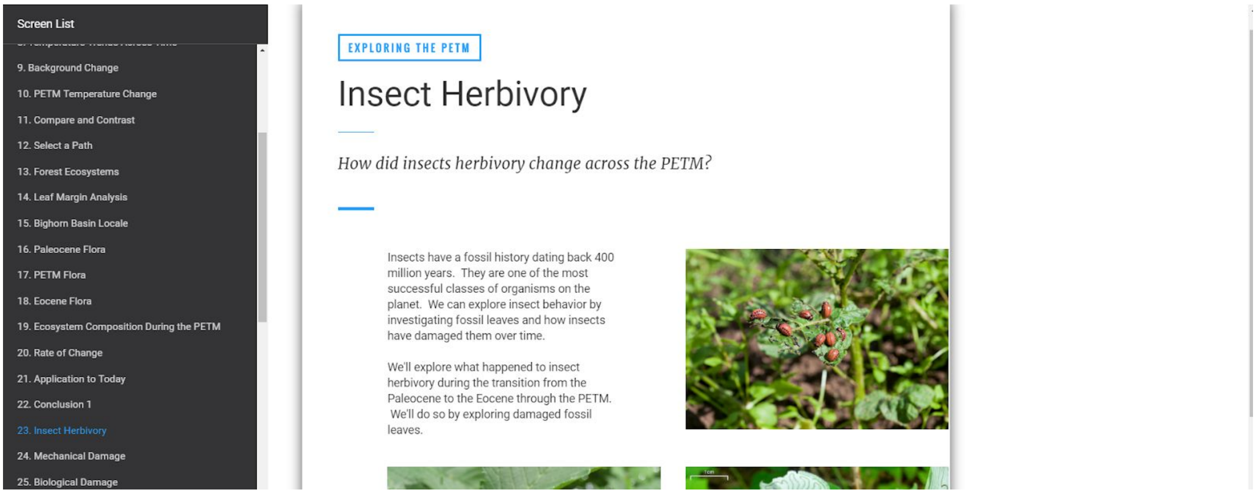


Screen 18 features a multi-step question built for the purpose of comparing common elements throughout different epochs.

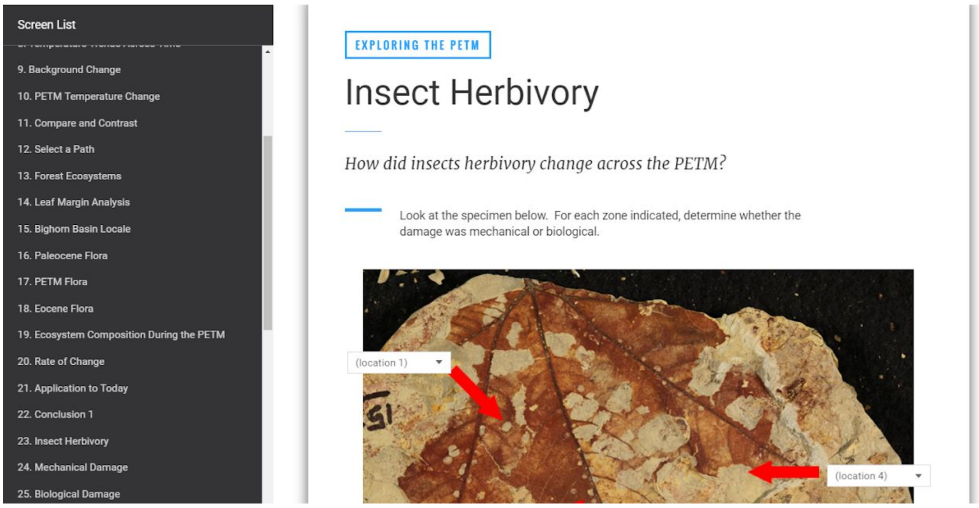


Forest Ecosystem instruction closes with a brief conclusion and applications to the real world today as students venture into a new pathway in upcoming screens.

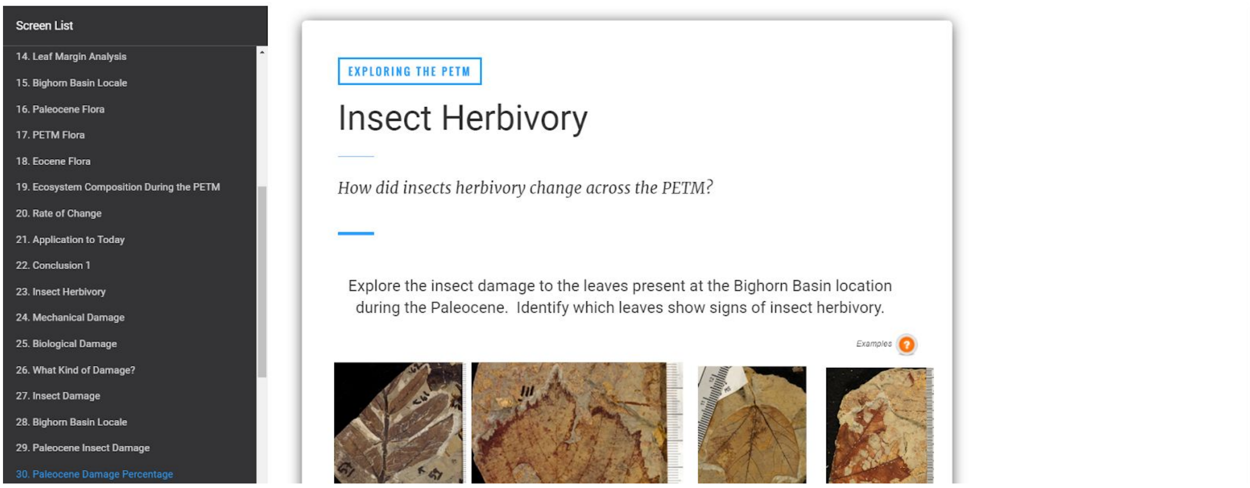
3) Insect Herbivory (Screens 23-39)



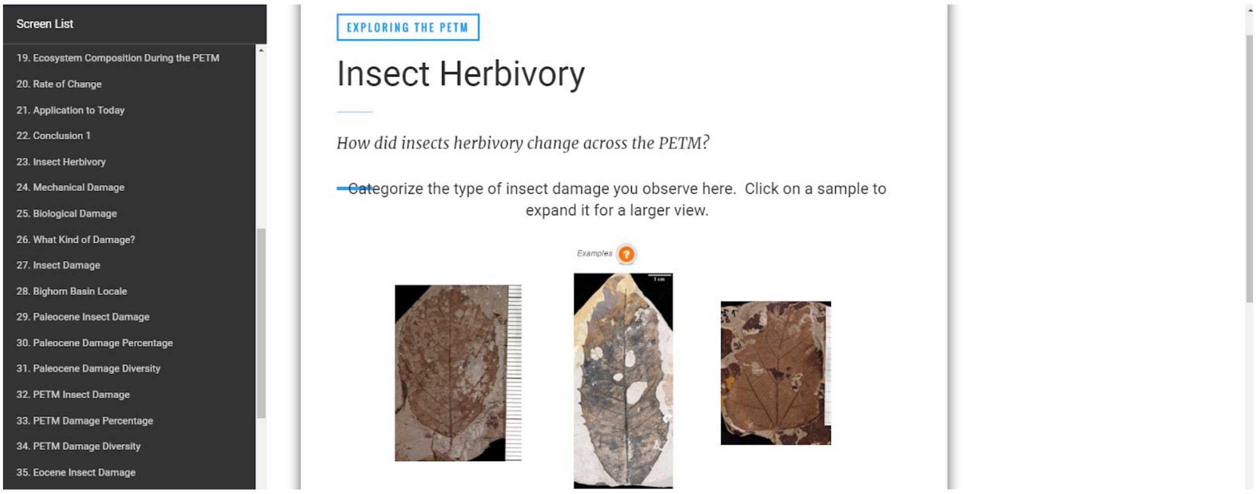
Insect Herbivory burrows into the fossil data from successful classes of organisms dating back 400 million years. Students are taken into the damage done to insect systems during the PETM as they progress through the next several screens.



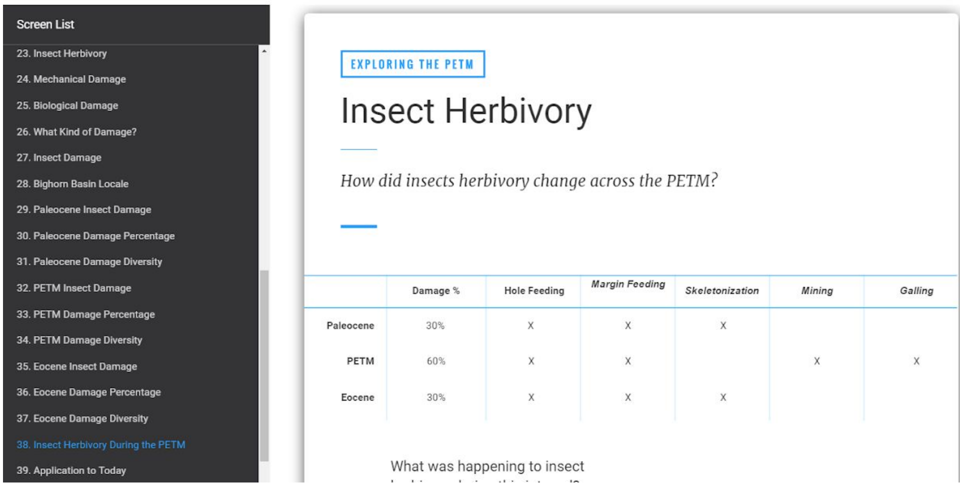
Students are tasked with determining the nature of damages done to specimens provided on the following screens, and learn to differentiate between biological and mechanical damage.



Screen 30 provides questions concerning the percent damage done during the Paleocene epoch and transitions into damage diversity and Eocene insect herbivory in the following screens.

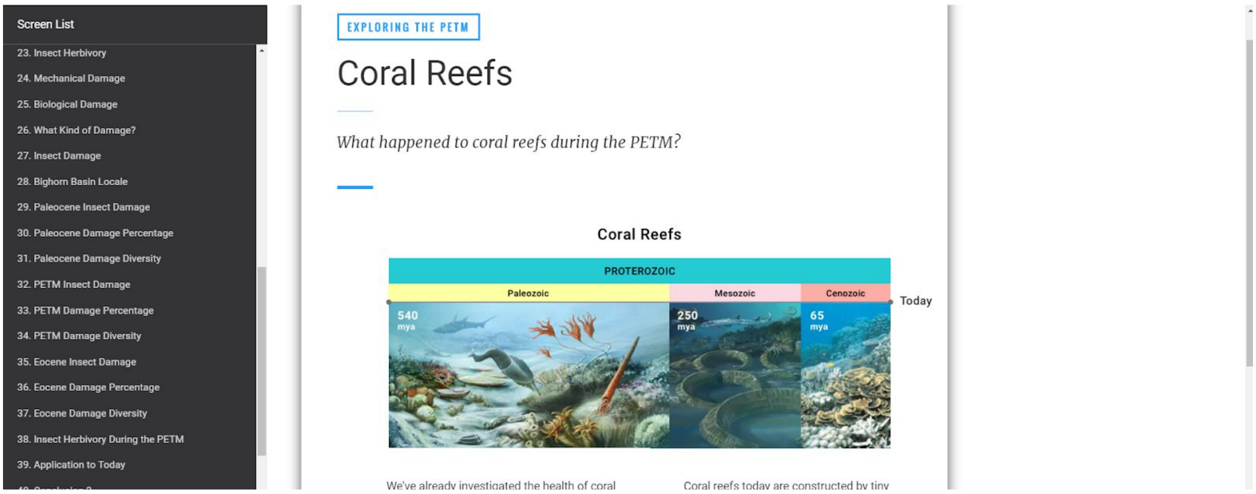


Insect Herbivory now enters the Eocene epoch as the student answers questions similar to those posed for the Paleocene epoch.

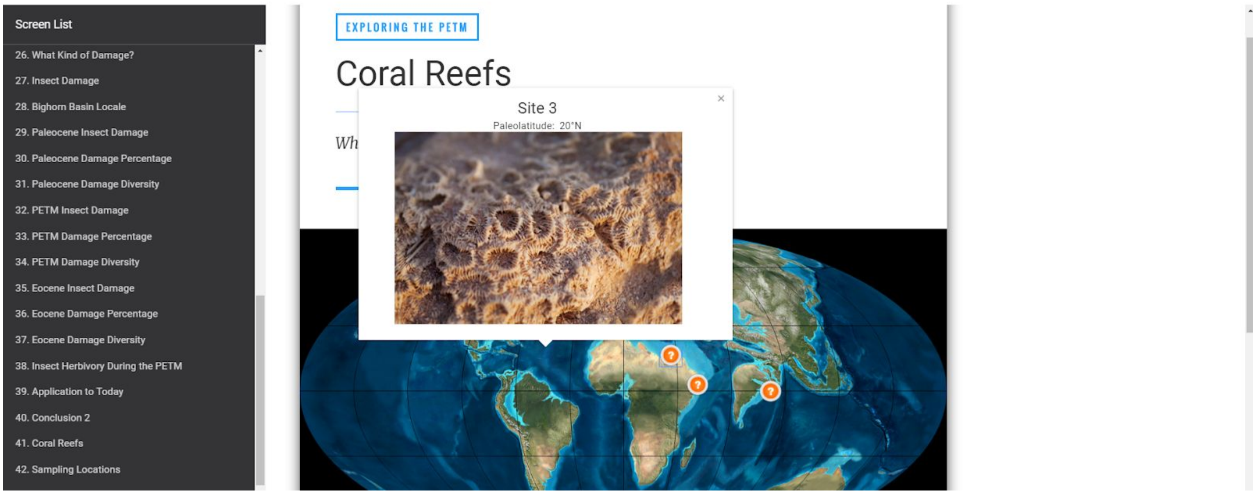


Screens 38-40 wrap up the exploration of Insect Herbivory with a brief conclusion and applications to today's world, as the student moves into his/her next pathway of exploration.

3) Coral Reefs (Screens 41-48)



In the next screens, students dive into the coral reefs and discover the features of the Earth’s vast coral reefs during the PETM.



Students begin by analyzing sample sites at varying Paleolatitudes and answer questions about coral composition.

Students are instructed to answer questions starting with the Paleocene and ending with the Eocene as they differentiate between Coralalgal and Foram-dominated reefs.

The Coral Reef instructional ends with a brief conclusion and applications to today's world, as students move to the conclusion of this unit while considering the effects of temperature on various biomes over time.

4) Consequences of a Warming World (Screens 49-54)

The consequences of warming are reinforced in the final screens of this instruction as students are asked various questions focused on ensuring a well rounded understanding of the PETM and how temperature affects the Earth’s habitats.

Students fill in a Blue Planet Report to condense all of the material of this lesson as the next few screens conclude the lesson and wrap-up the major components of this segment of instruction.

Unit 7 Blue Planet: Then and Now

Lesson Stats

- Average time spent: 1-1.5 hours

Learning Objectives

- Define, from observation and data, the roles of various components of the atmosphere as they influence climate.
- Describe and evaluate patterns of global climate change revealed through data, including the role of natural and anthropogenic processes.

Assessment

Max score: 139

Lesson Flow

- Introduction, Screens 1-4.
- US Case Studies, Screens 5-18.
- US Case Study Reflection, Screen 19.
- Australian Case Study, Screens 20-22.
- New Zealand Case Study, Screen 23.
- Coral Sea Case Study, Screens 24-27.
- Glacier and Ocean Temperature Case Study, Screens 28-31.
- Global Reef Bleaching Case Study, Screens 32-33.
- Revisiting Hypotheses and Summary, Screens 33-36.

Common Student Issues/Misconceptions

- Coming soon

Activity Walk-through

1. US Case Study Example

This screen shows the first case study students will encounter in this lesson. The later case studies follow the same format where students are asked to make observations and then answer thought provoking questions about global climate change.

2. US Case Study Review

After the US case study students must analyze and reflect on how the data in this particular case study relates to the larger question about global climate change.

3. Australia Case Study

After looking at the US case study and learning about data relations, students are tasked with formulating a hypothesis related to the environment of the next case study they will encounter Australia.

Unit 7 Blue Planet: Finding the Cause

Lesson Stats

- Average time spent: 1-1.5hrs

Learning Objectives

- Investigate what might be causing the recent and rapid temperature increase.
- Understand the different planetary factors that influence global temperature changes such as albedo, distance, atmosphere, and luminosity.

Assessment

Max score: 0

Lesson Flow

- Introduction and testing factors influencing temperature, screens 1-5.
- Investigating the albedo factor, screens 7-19.
- Investigating the distance factor, screens
- Investigating the atmosphere factor,

- Investigating the luminosity factor, screens 25-32.

Common Student Issues/Misconceptions
- N/A

Activity Walk-through
1. Factors that Influence Earth's Temperature

On this slide students will be prompted to consider which factors have the greatest impact on the Earth's temperature. On the slides that follow students will get have the opportunity to explore these factors through a simulations.

2. Selecting Factors

On slide five students can choose which factor they want to explore first. Each factor is explored over several slides using a simulation.

3. Investigating the Effect of Albedo on Earth's Temperature using a Simulation

Once students choose a factor to explore, albedo in this example, they are brought to a screen that prompts them to engage with a simulation. In this case the student is to enter Earth's albedo value into the white text box in the simulation labeled “Albedo”. Students can also adjust the value by dragging along the respective bar. Once a student enters in .31 they can hit enter or click the “Take Reading” button on the bottom of the simulation. The student will see that the “Effective Temperature” value has changed. Students will then take this value and convert it into Celsius by subtracting 273.

4. Investigating the Factor of Luminosity

Another factor students have investigate is luminosity.

5. Reflection and Consideration of Most Prominent Factors

On this slide students are presented again with some factors influencing the Earth and are asked to determine which of the factors has had the greatest effect based off their findings in the simulations.

Unit 7 Blue Planet: Keeping Balance

Lesson Stats

- Average time spent: 1 hour

Learning Objectives

- Define, from observation and data, the roles of various components of the atmosphere as they influence climate
- Describe and evaluate patterns of global climate change revealed through data, including the role of natural and anthropogenic processes

Assessment

Max score: XXX

Lesson Flow

- Introduction, Screens 1-2.
- Sources and Sinks, Screens 3-7.
- Geologic Simulation - Volcanic Activity, Screen 8.
- Geologic Simulation - Chemical Weathering, Screen 9.
- Biological Simulation - Cellular Respiration, Screen 10.
- Biological Simulation - Photosynthesis, Screen 11.
- Anthropogenic Simulation - Reforestation, Screen 12.
- Anthropogenic Simulation - Deforestation, Screen 13.
- Anthropogenic Simulation - Fossil Fuels, Screen 14.
- Geologic Simulation - over 100 years, Screens 16-17.
- Biological Simulation - over 100 years, Screens 18-19.
- Anthropogenic Simulation - over 100 years, Screens 20-22.
- Sources and Sinks Evaluation and Summary, Screens 23-27.

Common Student Issues/Misconceptions

- Students must make sure that all these variables are reset before starting their simulations. If they do not, they will have inaccurate CO_2 readings.

Activity Walk-through

1. Introduction to Carbon Sources and Sinks (Screen 3)

On **screen 3** students will learn the difference between a carbon source and a carbon sink and then be asked questions to ensure their understanding of the concept.

On **screen 7** students must use the drop down menu to label seven events as being either anthropogenic, biologic or geologic. Students can click on the image on the far right of the screen for definitions of terms.

2. Source or Sink Simulation - Formulating a hypothesis.

For the rest of the lesson students will use simulations to investigate different geologic, biologic, and anthropogenic variables and determine if they are carbon sources or sinks. To successfully run this simulation students must make sure all the variables are reset. The graph displays the levels of carbon dioxide over time. Students can change the timespan scale and see how that affects their data. Choosing a longer timespan makes the graphing trend easier to interpret . On **screen 8** students must manipulate the variable of volcanic activity and hypothesize if the variable is a carbon source or sink. Students will similarly formulate a hypothesis for the other sources.

3. Carbon Balance Simulation Introduction

Students are brought to this screen before running each simulation. From here they can click an image on the right side of the screen to start a simulation in the order of their choosing.

4. Simulation over 100 years - Anthropogenic: Fossil Fuels

On **screen 20** students will explore the impacts of Fossil Fuels over a 100 year time span. To begin, students must make sure that all the variables have been reset and that the timeline is set for 100 years. Students can then record the reading for CO2 and compare that to the initial reading to see if it increased or decreased.

5. Simulation over 100 years - Biological Factors (Screen 18)

On **screen 18** students will explore the impacts of biologic factors over a 100 year time span. To begin, students must make sure that all the variable have been reset and that the timeline is set for 100 years. Students can then record the reading for CO_2 and compare that to the initial reading to see if it increased or decreased.

6. Simulation over 100 years - Geologic Factors (Screen 16)

On **screen 16** students will explore the impacts of geologic factors over a 100 year time span. To begin, students must make sure that all the variable have been reset and that the timeline is set for 100 years. Students can then record the reading for CO_2 and compare that to the initial reading to see if it increased or decreased.

7. Sources and Sinks Evaluation and Summary (Screen 23-25)

Unit 7 Blue Planet: Designer Planet

Lesson Stats

- Average time spent: 1.5 hours

Learning Objectives

- See Instructor's Guide

Assessment

Max score: 95

Lesson flow

- Cover and Introduction, Screens 1-2
- Consequences of Warming and Selecting a Limit, Screens 3-4
- Emission Sectors/First Test, Screens 5-16
- A Climate Intervention, Screens 17-30
- A Climate Change/Second Test, Screens 31-35
- Conclusion, Screen 36

Common Student Issues/Misconceptions

- The simulation breaks down contributions by sector - to find the overall temperature rise students must read the uppermost line on the graph, except when climate intervention technologies are added
- When adding in climate intervention technologies, students must read the lowest black line to find the overall temperature.

Simulations

Simulation name: Emissions Simulation

- Description: The emission simulation engages the student with the ability to change how four major emission sources (Transportation, Buildings, Power/Energy, Land Use) are used in the future. Students can change the attention given to a source by selecting between levels ranging from ‘no effort’ to ‘high effort’ and set a year in which to begin. This allows the student to actually visualize our planet as a dynamic body which holds onto the things we put out into it, and how human activity over time can dramatically alter the path we are headed on.
- Correct answer:

Activity Walk-through

1) Consequences of Warming and Selecting a Limit (Screens 3-4)

Students begin their journey by thinking on the impact of warming on the planet and how much of a difference 2 degrees Celsius could make. Students can select through 5 categories (Water, Food, Coasts, Health, Ecosystems) to discover the answers. Students will then select a ‘warming limit’ and continue onwards through the unit to learn just how much temperature and emissions can affect the future.

2) Emission Sectors and First Test (Screens 5-16)

Students now begin the simulation portion of this section as they select a sector of emissions to explore via the simulation. Students will go through four areas of CO2 emission (Transportation, Buildings, Power/Energy, Land Use) as they learn about how humans affect Earth.

Students can visualize how small changes in effort can make a big difference in the outcomes, as they prepare to understand how we can contribute to lowering emissions.

Students will utilize previous knowledge to calculate where Earth would stand given that society put in the ‘maximum effort’ to reduce temperature change.

Students now revisit their previous threshold and test its feasibility. Here, a new threshold is selected if needed, and students move forward into understanding the costs of reducing global temperature change.

As the simulation on emissions and temperature changes wraps up, students answer brief questions on if they believe we can achieve the goal set by countries for the future.

3) A Climate Intervention (Screens 17-30)

Students now reflect on factors which affect the Earth's temperature and posit potential new ventures that may help keep the temperature at bay.

Screen 20 reintroduces the student to Albedo, which was covered previously in *Finding the Cause.* Students will answer questions about man-made aerosols and think about what effect they may have if added to the atmosphere.

Screens 23-24 discuss solar luminosity and it's delicate relationship with life on Earth. Students contemplate the effects of an altered solar luminosity and how it might affect us here on Earth.

Screen 25 whisks the student into the concept of removing CO_2 from the Earth. Here, the student will answer concept based questions on how CO_2 interacts with the Earth.

Instruction continues with the student thinking about why storing CO_2 may or may not be beneficial as the unit moves into the Biomass section.

Biomass! The stuff of life, and an alternative approach to reducing the levels of CO_2 present in the atmosphere is discussed in this section as students contemplate the effects of having more photosynthetic life on Earth.

Having interacted with many angles of approach to CO_2 reduction, students now set the simulator level to what they deem appropriate as the lesson moves onto the next section.

4) A Climate Change/Second Test (Screens 31-35)

Students are now tasked with building the future by choosing how to combat global temperature change through the previously explored avenues.

By toggling through options, students must select the best measures to battle against the projected temperature gain.

Students must deal with the realities of their choices and think to understand the human consequences that will have to be endured in order to meet their goal.

To be sure, the main effects will be on the environment! As such, students will discuss the effects left on the environments and biomes of the planet with their plan in mind.

5) Conclusion (Screen 36)

Students conclude their journey and finalize their Blue Planet Report as they reflect back on the wealth of information explored in this unit.

Unit 8 A Mission Beyond: Getting Started

Lesson Stats
- Average time spent: 15 min

Learning Objectives
- To understand the expectations for this unit and what will need to be done in order to successfully complete it.
- To understand the mission that students will embark on throughout this unit.
- Shows students that they will further understand the fundamentals of how their body operates, how its various systems are affected by spaceflight, and how they can use this knowledge to better their own health on Earth.

Assessment
Max score: 0/0

Lesson flow
- GETTING STARTED How to Access Lessons
- Completing your training
- Contact with Mission Control
- Planning your Mission
- Your Mission
- Why Mars
- Learning Outcomes

Common Student Issues/Misconceptions
None

Activity Walk Through
- Students are required to upload information about their mission to Mars such as the time and distance required in the My Mission Beagle app.

- Students will have to determine the duration of flight and the distance to Mars. They will also need to describe why a mission to Mars is important.

Unit 8 A Mission Beyond: Making the Dream Team

Lesson Stats

- Average time spent: 30-45mins

Learning Objectives

- Learn about what qualifications potential astronauts need to have in order to qualify for an extended space flight.

Assessment

Max score:

Lesson flow

- Cover and Introduction, Slide 1
- Activity: What Makes a Good Astronaut?, Slides 2-4
- Qualifications, Slides 5-7
- Balancing Roles, Slide 8
- Pause and Reflect, Slide 9
- Summary and Mission Control, Slide 10

Common Student Issues/Misconceptions

Activity Walk-through

- Astronaut Qualities Brainstorm

This is the first content slide students see for this lesson. Here they will begin to brainstorm some of the qualities they think astronauts need to possess in order to be successful. As per the instructions listed on the page, students will drag and drop the images and words from the left into the right box. There is no incorrect answer or combination of qualities.

- **Qualities and Qualifications of Astronauts Examples**

This slide helps students become generally acquainted with the qualities and qualifications of real life astronauts. The minimum requirements will be covered in the following slides.

- **Activity: What to Look for when Selecting a Crew**

On Slides 5, 6, and 7 students will learn about what qualities and qualifications potential astronauts must have in order to qualify for a mission to space. Students will look at the applicant's relevant education and experience, medical history, and personality to ensure a safe flight with compatible teammates. Here students can practice selecting the most qualified individuals from a pool of applicants.

- **Summary and Selecting a Crew**

On slide 10, the last slide of this lesson students will click on the Beagle icon to open up the "My Mission" Beagle app. The Beagle icon is located in the upper righthand corner of their slide.

Once students open up My Mission app, their first task is to select four crew members from a pool of applicants. Students must read the "resumes" of each crew member to assess their relevant education and experience, health history, and personality. Students must select one engineer, medic, pilot, and commander in order to ensure that all roles are filled.

Unit 8 A Mission Beyond: Unseen Danger: Radiation

Lesson Stats
- Average time spent: 45 min

Learning Objectives
- To understand the risks to astronauts associated with radiation in space.

Assessment
Max score: 18

Lesson flow
- Introduction (Slide 2)
- Surrounded by Radiation (Slide 3)
- What is Radiation? (Slide 4)
- Types of Radiation (Slide 5)
- What's the Problem? (Slide 6)
- Health Effects on Astronauts (Slide 7)
- The Dangers of Space Radiation (Slide 8)
- Protecting Yourself (Slide 9)
- Pause and Reflect (Slide 10)
- Summary (Slide 11)

Common Student Issues/Misconceptions
N/A

Activity Walkthrough
- Surrounded by Radiation (Slide 3)

Students are given an explanation for why astronauts saw flashes of light in their eyes while in space. Students are then told what radiation is and how it is actually a part of our everyday lives.

- Types of Radiation (Slide 5)

Students are given descriptions of two kinds of radiation in outer space and are then asked to sort the forms of radiation into the appropriate category.

- Health Effects on Astronauts (Slide 7)

The flashes of light are further explained on this screen and students are told about the acute and chronic effects of radiation. Students are then asked to rate how important it is to combat radiation to complete a successful mission to Mars.

Unit 8 A Mission Beyond: The Bare Bones

Lesson Stats

- Average time spent: 30-45mins

Learning Objectives

- Describe the function of the skeletal system
- Explain how bones are living tissues
- Illustrate the role of calcium in maintaining the structure of bones.

Assessment

Max score: 42

Lesson flow

- Cover and Introduction to the Skeletal System (Slides 1-10)
- Bones and Why are Bones Important? (Slide 11-12)
- Bone Functions (Slides 13-17, 23)
- Calcium (Slides 18-22)
- Summary (Slide 25)
- Mission Control Meal Plan Activity.

Common Student Issues/Misconceptions

- At the end of the lesson students may forget to go into their “Mission Control”. It is important that they continue right after the lesson so that what they learned is still fresh in their minds.

Activity Walk-through

1.) Introduction (Slide 2)

- This is the second slide students see when they begin the lesson. Here they will be oriented with the goal of the lesson, learn about the skeletal system and the important role diet plays in maintaining bone health.

2.) The ROS Report (Slide 3)

On the third slide students will see for the first time the Risk of Spaceflight (R.O.S.) report. Throughout the unit students will see several of these reports, each investigating a different problem faced by astronauts. This particular R.O.S report covers the negative impact spaceflight has on bones, and features quotes from astronauts.

3.) Choosing your Path (Slide 10)

Depending on how familiar students are with the skeletal system they can choose to skip a review or dive right into the rest of the lesson which goes into detail about the function of bones and their composition.

4.) Which Bone is Which? (Slide 11)

If students choose to review bones back on slide 10 they are brought to this slide where they must correctly name some of the bones of the body.

5.) What are Bones Made of? (Slide 14)

After a brief cover of the function of bones and how they are made, students learn what bones are composed of and are introduced to the important role of calcium in bone health.

6.) Calculating Calcium (Slide 19)

Following from the previous slides detailing the importance of calcium, students are next tasked with figuring out how much calcium an individual needs to maintain their bone health and determining good dietary sources of calcium.

7.) Summary

Slide 25 of this lesson directs students to open up their My Mission beagle app where they will be able to personally create a dietary plan for each of their astronauts that ensures bone health.

8.) Mission Control Meal Planning

After opening up Mission Control the student will go to the crew section tab to choose their crew if they have not yet done so. Then, they will click on the small profile pictures of the crew members located on the red “Mission Design Plan” Bar.

After clicking on an individual's profile the student will need to select “Meals” in the upper righthand corner of their Mission Design Plan to see a list of the meal options. These meals are designated with letters of the alphabet (A,B,C,D,etc.). Students must select meals for each day of the week and ensure that their average for daily calcium is at least 1000mg.

Unit 8 A Mission Beyond: Lifting Tons and Skeletons

Lesson Stats

- Average time spent: 45min-1hr

Learning Objectives

- Identify microgravity as a unique stressor affecting humans in space
- Distinguish the activities of three different bone cells as it relates to bone remodeling
- Develop a hypothesis that explains how loading affects bone formation
- Evaluate various exercise-related countermeasures in their ability to prevent bone loss in space

Assessment

Max score: 44

Lesson flow

- Cover and Introduction (Slide 1)
- Being in Space (Slides 2-3)
- Bones in Space (Slides 4-5)

- Bone Remodeling (Slides 6-7)
- Your Life (Slides 8-9)
- Summary (Slide 10)

Common Student Issues/Misconceptions

- At the end of the lesson students may forget to go into their "My Mission" Beagle app. It is important that they continue right after the lesson so that what they learned is still fresh in their minds.

Activity Walk-through

1.) Differences Between Earth and Space (Slide 2)

On this slide, students will get started thinking about the differences between the Earth and space. A key difference they should consider is gravity.

2.) Gravity and Microgravity (Slide 3)

On this slide students will be introduced to the concept of gravity and learn that there is a small amount of gravity in space, referred to as microgravity.

3.) The Effect of Microgravity on Bones (Slide 4)

Here students will need to drag and drop the star onto the skeletal region they think will be most affected by microgravity.

4.) How Bones are Made (Slide 5)

On this slide, students will learn about the cells responsible for building and breaking down bones.

5.) How Loading/Weight affect Bones (Slide 8)

Near the end of this lesson students will be asked to think about the influence of load on the skeleton. On Earth, with gravity in effect, the skeleton is naturally under a load while in space this load is significantly smaller.

Unit 8 A Mission Beyond: Getting Under Your Skin

Lesson Stats

- Average time spent: 45min-1hr

Learning Objectives

- Describe the lack of direct contact with sunlight as a unique stressor to spaceflight
- Synthesize experimental data to explain how a lack of sunlight can lead to a vitamin D deficiency
- Analyze the concept of homeostasis through the body's reaction to low vitamin D levels.
- Evaluate the efficacy of a meal plan as it pertains to vitamin D and maintaining bone health in space.

Assessment

Max score: 85

Lesson flow

- Sunlight, Slides 1-7
- Vitamin D and Bone Functions, Slide 8, 15-21
- Summary, Slide 9
- Calcium and Bone Functions, Slides 10-14
- Metacognition, Slide 22
- Summary, Slide 23

Common Student Issues/Misconceptions

- At the end of the lesson students may forget to go into their "Mission Control". It is important that they continue right after the lesson so that what they learned is still fresh in their minds.

Activity Walk-through

1.) Sunlight Absorption on Earth and Space

On the fourth slide students will start thinking about and be introduced to the relationship between bone loss and a reduction in sunlight.

2.) Positive and Negative Effects of Sunlight

On this slide students will come to understand that sunlight can be both both harmful and beneficial to health.

3.) The Relationship Between Calcium and Your Bones

The positive relationship between sunlight and bone integrity is described in this slide. A reduction in sunlight will lead to a reduced production of vitamin D, which is needed to facilitate the absorption of calcium. Lower calcium absorption will lead to weaker bones.

4.) Understanding Regulation of Bone Growth and Breakdown

On this slide students learn about the complexly regulated process called homeostasis and how that specifically relates to bone growth and break down.

5.) How much Vitamin D is needed?

On this slide students will learn the minimum daily requirement for Vitamin D and calculate the percentage of vitamin D in some of the food they eat.

6.) Summary and Mission Control

This is the last slide students will see and are instructed to open up mission control and check that their crew members are getting enough Vitamin D in their diets.

Unit 8 A Mission Beyond: Maintaining Peak Performance

Lesson Stats

- Average time spent: 1.5 hrs

Learning Objectives

- Describe the types of muscles and the functions of the muscular system.
- Explain how muscle cells are affected by microgravity.
- Use evidence gathered from this lesson to explain how to prevent muscle loss due to microgravity.

Assessment

Max score: 119

Lesson flow

- Cover and Introduction (Slides 1-2)
- The First Humans on Mars (Slide 3)
- What is going on? (Slides 5-6)
- Starting with the Basics (Slides 8-9)
- Types of Muscles (Slides 10-13)
- Taking a Closer Look (Slides 14-17)
- What's the Problem? (Slides 20-23)
- The Bigger Picture (Slides 25-26)
- Making a Prediction (Slide 27)

- Summary (Slide 28)
- Countermeasures (Slides 29-30)
- Proteins (Slides 31-32)
- Pause and Reflect (Slide 27)
- Your Recommendations (Slide 38)
- Summary (Slide 39)

A Common Student Issues/Misconceptions
N/A

Activity Walkthrough

- Slide 10: 3 Types of Muscle

The three types of muscles are explained to students and then students are asked to match each video to the type of muscle that is shown in the videos.

- A closer look (Slide 19)

Students are shown the differences between actin and myosin. They are then asked to sort the statements at the bottom of the screen into true and false statements.

- The bigger picture (Slide 25)

This screen shows students how a lack of loading as a result of microgravity can affect muscle mass. Students are then asked to complete the table below using what they now know about muscle loss. They will need to drag and drop a picture and a description.

- What is protein, really? (Slide 31)

Students are given information regarding protein and told to determine how protein would be important for a crew on their mission. This is important in that students will need to take this information and reevaluate the diets they have put their crew members on and ensure that all members are receiving enough protein.

- Choosing your exercise, Slide 35

Students are told about muscle atrophy in the previous screen and will have to use that knowledge to determine which exercise would be most beneficial in stimulating muscle that is affected by microgravity.

- Meal plan calibration, My Mission Beagle App

Students are expected to calibrate their meal plan to ensure each astronaut is receiving enough protein. This is done in the My Mission Beagle app.

Unit 8 A Mission Beyond: Counting Calories

Lesson Stats

- Average time spent: 45min-1hrs

Learning Objectives

- Find out what a calorie really is.
- How much energy does a human require?
- How can we perform an energy balance on an organism?

Assessment

Max score: 72

Lesson flow

- Cover and Introduction, Slides 1-4
- Calories and Caloric Intake, Slides 5-17
- Calories and Basal Metabolic Rate (BMR), Slides 18-21
- BMR and Exercise, Slides 22-23
- Calculating the Thermic Effect of Food (TEF), 24-25
- Calorie Intake and Balancing Energy Outputs and Inputs, 26-28
- Reflection and Summary, Slides 29-32

Common Student Issues/Misconceptions

N/A

Activity Walk-through

1.) **Finding energy in food**

On this slide students will use their knowledge to select where a considerable amount of energy is stored on this food label and drag and drop the star to that component.

2.) **Calculating Calories: Inputs and outputs**

This slide provides students with a general schematic of how calories are used in the body. The following slides will show the different ways that calories are burned that include BMR, exercise, and the thermic effect of food.

On slide 30 students will investigate how many calories the body burns to just maintain its basic functions. This is called the Basal Metabolic Rate and is dependent on age and gender.

Students will also investigate another caloric output, exercise and add that into the total number of calories a person burns.

On slide 25 students will learn about the thermic effect of food (TEF) and factor that output into their calculation for how much energy they need to consume in order to be have an energy balance.

3.) Summary

Once students finish the lesson they are again directed to a summary slide and tasked with setting the correct caloric targets for each crew member onboard their mission. To do this students must open up the “My Mission” Beagle app in the upper right hand corner of their screen and select a crew of 4 if they have not done so in a previous lesson.

Once students open up their mission control they will see their selected crew. On the red bar labeled “Mission Design Plan” students will see small circular profile pictures of their crew members. Clicking on these will bring up the individual's personal profiles.

Here is an example of a personal profile. Before you can start making a meal plan, you’ll have to set a target caloric intake for each crew member. In this lesson you learned that the amount of calories consumed must equal the sum of an astronaut’s BMR, calories burned from exercise and the thermic effect of food.   The BMR for each astronaut is provided next to their profile picture. The amount of calories they will burn from exercise will be based on the routine you set for them. To set an exercise routine, first set a target exercise time. You will then be allowed to construct an exercise plan using the plans displayed in the top right corner of your planning page.

Unit 8 A Mission Beyond: Fueling Your Team

Lesson Stats

- Average time spent: 45mins-1hr

Learning Objectives

- What are the macronutrients in food?
- How does the body maintain stable levels of energy?
- How does the body react to a prolonged energy shortage, and how would that affect a Mars Mission?

Assessment

Max score: 105

Lesson flow

- Cover and Introduction, Slides 1-4
- Components of Food - Macronutrients and Carbohydrates, Slides 5-13
- Homeostasis and feedback mechanisms, Slides 14-19
- The Body Without Food, Slides 20-29
- Summary and Reflection, Slides 30-33

Common Student Issues/Misconceptions

N/A

Activity Walk-through

1.) **The Macronutrients Found in Food**

On this slide students can hover over the image of different foods to find out what they are composed of i.e. the percentage of protein, fats, carbohydrates, etc.

2.) Reading Nutrition Labels (Slide 10)

On this slide students will learn how to calculate the amount of calories that can be gained from different kinds of macronutrients such as carbohydrates, proteins, and fats. Per gram, fat contains more calories than either carbohydrates or protein.

3.) **Low Glucose Levels (Slide 13)**

On this slide students will need to click on the little question marks on the “Blood Glucose Level” dial located at the bottom of the page to explore what happens to a person with varying levels of blood glucose.

4.) Glucose Regulation After a Meal (Slide 15)

On slide 15 students will get to explore the role of the pancreas in blood glucose regulation. The dots with arrows pointing to them are the different substances the pancreas secretes, such as insulin that are necessary for blood sugar regulation.

5.) How the Pancreas Functions

Slide 16 details how the pancreas “senses” and responds to increased levels of glucose in the body. Students are to match the order in which insulin is excreted after food enters the stomach and then the bloodstream.

6.) First Phase of Glucose Deprivation

Students can click on the circle labeled “Glucagon” to remember its role in glucose metabolism.

7.) Second Phase of Glucose Deprivation (Slide 24)

On slides 24-25 students will learn what happens eight hours after the body is deprived of glucose. They will need to read and interpret the two graphs on the slide to answer the questions.

8.) **Third Phase of Glucose Deprivation (Slide 27)**

Students learn that in the third phase of glucose deprivation the body begins to degrade its own protein and essentially starves.

9.) Three Phases Summary Slide (Slide 29)

Using the knowledge gained reviewing the different phases of glucose deprivation students will need to drag and drop the descriptions on the right hand side to accurately describe each phase.

10.) Summary and Transition to Mission Control

After this slide students will open up the “My Mission” app in Beagle to adjust the meal plans of their crew members to ensure they have a well balanced diet. Specifically, students will ensure that each astronaut is receiving at least 250 grams of carbohydrates each day.

Unit 8 A Mission Beyond: Knocked Out

Lesson Stats

- Average time spent: 1.5 hrs

Learning Objectives

- Describe the function and components of the cardiovascular system.
- Explain how oxygen is delivered throughout the body.
- Explain how shifts in blood volume during spaceflight can lead to fainting that is experienced by astronauts.

Assessment

Max score: 76

Lesson flow

- Cover and Imagine this!. Slides 1-2
- What's going on?, Slides 3-5
- You Task, Slide 8
- Contents Sort, Slide 10
- How is Oxygen Delivered, Slide 12
- Construct the system, Slide 15
- Label the System, Slide 16
- Providing Oxygen, Slide 17
- Getting more oxygen, Slide 19
- Blood Distribution, Slide 21
- Puffy faces, thin legs, and more, Slide 22
- Pause and reflect, SLide 25
- Conclusion and summary, Slides 27-28

Common Student Issues/Misconceptions

N/A

Activity Walk-through

- What's the problem?, Slide 6

Students will have to take a look at the R.O.S Report from Mission control to get a better idea about how fainting can hinder a mission to Mars. After reading through this report, students will be asked to determine what they have learned from the report and answer questions based on it.

- Your task, Slide 8

Students are given their task and told to find out what specifically is happening in the body to cause astronauts to faint in space. They will be focusing on how blood flow changes can lead to fainting.

- How is oxygen delivered, Slide 12

Students will determine how oxygen is delivered by centrifuging the vial seen on the screen. By doing so, they will see a separation in the vial between plasma, the buffy coat, and the RBCs.

- Label the system, Slide 16

Students will be asked to label the components of the cardiovascular system to the appropriate area in the diagram. This will help them identify what each part is and how blood flows.

- Blood distribution, Slide 21

Students will be asked to determine how transitioning from Earth to microgravity would affect the distribution of blood in our bodies by learning about orthostatic intolerance.

- Anti-gravity spacesuits, Slide 26

Students will be asked to determine how to counteract orthostatic intolerance which occurs because of increased gravity, forcing blood to pool in the feets and legs.

Unit 8 Human Spaceflight: A Change of Heart

Lesson Stats

- Average time spent: 2-2.5hrs

Learning Objectives

- See Instructor's Guide

Assessment

Max score: 71

Lesson Flow

- Introduction to Cardiovascular System, Screens 1-5
- Tracing the Path, Screens 6-7
- Cardiac Output and Understanding, Screens 8-11
- A Full Heart & Change of Heart, Screens 12-20
- Pause & Reflect, Screens 21-22

1. Introduction to Cardiovascular System, Screens 1-5

Working on Mars will be no easy task! Here, students will begin their exploration of the stresses that the body deals with on a day-to-day basis on Earth, as they work towards applying the same principles to a Martian habitat. Students will begin with a range of physical activities which they select from to see what happens in the body during the activity.

(Screen 4)

Feeling the burn? The goal here is to personalize the lesson by appealing to a diverse range of students with various hobbies and goals.

Tracing the Path, Screens 6-9

Now students will dive into the circuitry of the human heart, and see just how all of that blood gets pumped from here to there! They will begin by differentiating pulmonary circulation from systemic.

(Screen 7)

Students learn about systole and diastole and how the various parts of the human heart work towards one mission. After one question, students will see this next screen which is a small activity to test their understanding:

Cardiac Output and Understanding, Screens 8-11

Cardiac output will quickly touch on graphing skills, and ask how exercise intensity affects the heart's activity levels.

(Screen 9)

Many students will be familiar with this diagram from primary education, but BioBeyond will ask the students some basic questions about the diagram and oxygen levels before going deeper.

(Screens 10-11)

More about how volume affects force, and tying together some concepts that will no doubt be essential to understanding the rest of the lesson. Some of these are very basic, but they are intended more-so for those students who have not been actively academic in the recent past.

A Full Heart & A Change of Heart, Screens 12-19

(Screens 12-13)

Alas, Astronauts! Now students apply previous concepts to the idea of open space and astronauts by thinking more about how *much* the heart can do. These questions will address end diastolic volume (EDV) and blood volume loss.

(Screen 14)

This screen has more instruction on how the heart responds to more stress, and asks the student to predict how the heart would respond to a decrease in blood volume entering it.

(Screen 15)

But what’s the evidence? Here we show students data of the mass of the heart changing after prolonged spaceflight.

(Screen 16)

Now that the students have an understanding, we test it by having them line up the changes in the body depending on what has happened to the heart. All of this would be *very* troubling for an astronaut (or anyone really!).

(Screen 17)

What *is* cardiac deconditioning? What are the consequences? Students learn about the idea of deconditioning and how it can play a significant role in our lives. So how do we counter atrophy? The next screens present some ideas on what we can do!

(Screen 20)

Wrapping up, the lesson presents some things that NASA has tried and tested with astronauts floating up above us! Students are asked questions about how much activity is appropriate to keep the body healthy in space.

(Screen 21-22)

After reflection, students write a short paragraph on their own recommendations based on what they have learned thus far in the unit!

Unit 8 A Mission Beyond: Launch Simulator

Lesson Stats

- Average time spent: 45 min

Learning Objectives

- Students are expected to launch their mission to Mars from this lesson. Students are asked to make final adjustments to their mission design plan before they launch. During launch students will get the chance to see if the plan they set up was successful or not. If they fail, they can always go back to the lessons, make adjustments and return to the Launch Simulator at any time.

Assessment

Max score: 300 points

Lesson flow

- Introduction (Slide 1)
- Launch SIM (Slide 2)
- What Next? (Slide 3)
- End of Lesson (Slide 4)

Common Student Issues/Misconceptions

N/A

Activity Walkthrough

- Spacecraft Selection or Readjustment

Students will be expected to have selected a spacecraft for this mission.

- Crew Selection

Students will be expected to have selected their crew and also determine their meal plan and exercise regime in the prior lessons.

- Launch Simulation

- Students will launch their mission and see how far they get. If they do not make it the whole way that is perfectly fine. They will then be directed to revisit (or visit for the first time) prior lessons in the unit in order to understand what they need to fix so that their mission to Mars can be successful.

During their mission, students can click on the profile picture of any astronaut and see how well they are doing on a variety of parameters. If their muscular function is low, they can click on the icon next to that meter and see that they will need to focus on adjusting the crew member’s carbohydrate intake, caloric consumption, or their resistive exercise.

To readjust a crew member’s meal or exercise plan, you can click the “change plan” icon on the crew member’s profile page. This will allow you to readjust plans while on board the spacecraft. You will not have all the meal plans accessible while you are in space. You will only have “Plans Onboard” which are meal plans E through L.

By adjusting this crew member’s caloric intake (ie. by swapping in meal plans that are more rich in calories), I was able to increase his muscular function. In a similar way, you can try to adjust the plans of your other crew members where and if necessary.

If, for example, as in the case above, students fail, the cause of failure will be shown in a failure report. In this case, the mission failed as a result of “inadequate crew selection”. Revisiting the crew selection lesson can help them before they give the Launch Simulation another try.